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SOIL TEMPERATURES AT WINNIPEG, MANITOBA

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Following the installation of a set of eight electrical resistance thermometers, soil temperature readings have been taken at various depths weekly since October, 1929. These thermometers were installed under the supervision of Mr. J. Patterson, Director of the Meteorological Service of Canada, and the late Professor S. C. Lee, and records have been kept by the Physics Department of the Manitoba Agricultural College. The thermometers are located in a grass plot about one hundred feet south of the Physics building at the following depths: Surface, 4 inches, 10 inches, 20 inches, 40 inches, 66 inches, 9 feet, 15 feet. A hole was made to a depth of about eight feet, large enough to allow a person to make small auger holes in the walls of the larger hole in such manner as was necessary to reach the various depths. The thermometers, protected by a waterproof covering, were placed in these auger holes, and the soil replaced in as nearly as possible the same condition as before removal. The wires from these thermometers, together with the compensating wires, were brought into the building underground in a waterproof tube. With the careful replacing and tamping of the soil, and the fact that the records published in this paper were taken at least four years after the installation it is probable that the condition of the soil in which these temperatures were taken was very similar to its condition before it was disturbed. The resistance of each thermometer was measured by the bridge method and these resistances converted to degrees Fahrenheit by reference to a previously prepared calibration chart.

PREVIOUS WORK

Callendar and McLeod (*1*), (*2*), used platinum wire resistance thermometers at depths similar to those in this investigation with the omission of the 15-foot depth, and the surface thermometer, giving special attention to the conditions which effect soil temperature. Harrington (4) reported a similar investigation conducted at Saskatoon, using eight thermometers at depths varying integrally from 1 to 8 feet and having the temperatures automatically recorded.

Smith (6) made a study of the interrelations between the temperature of the surface soil and the atmosphere immediately above it and found that by the use of an enlarged bulb thermometer the temperature of the surface soil was lower than that of the air in contact with it just before sunrise on calm nights.

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Kimball, Ruhnke and Glover (*5*) report very considerable lag in the response of soil to air temperature changes and also that the time lag increases with depth. In 4 inches of soil there was a lag of 6 to 7 hours and at 12 inches a lag of 10 hours. They also found the maximum temperatures to be in descending order in all cases: Air; soil at 4 inches, 12 inches, 24 inches, and that no soil approached the air maximum temperature within 10° F. or came within 20° F. of the minimum.

SOIL TYPE

The nature of the soil in which these thermometers were exposed will necessarily have considerable bearing upon the records obtained. Of special importance is its moisture holding capacity, since the thermal conductivity would depend to a considerable extent on the moisture content.

The following description of the soil in which the thermometers were placed has been kindly submitted by Professor J. H. Ellis, Soils Division, Agronomy Department, Manitoba Agricultural College:

> "The clay deposits of the Lake Agassiz basin, which extend throughout the level topography of the Winnipeg area, have been described by Wallace and Maynard (*7*). At the point where the thermometers are located five distinct deposits occur.
>
> 1. The surface deposit of lacustrine clay extends to the lower fourth and the upper part of the fifth foot. This has been modified at the surface by man and contains considerable concretionary lime carbonate from soil weathering in the lower portion.
> 2. This clay sediment is underlaid from the fifth to the seventh foot by a deposit of marly, very fine sandy clay, which is more or less laminated.
> 3. Below this second deposit deep lacustrine fine clay occurs.
> 4. In the ninth foot a band of yellowish brown iron stained silt extends horizontally from four to six inches in depth, which was deposited during a period of temporarily shallow water.
> 5. Below this band the deposit consists of the closely packed, grey and brownish grey, laminated varve clays deposited in the deep waters of Lake Agassiz. This deposit extends considerably below the depth of the lowest thermometers.
>
> The soil, which has developed on the surface deposit may be described as a slightly degraded clay chernozem. It has developed under woodland invasion of prairie from which the trees were removed in 1911-12 and seeded to lawn grass about 1915. The chief soil characteristics may be noted as follows:

A horizon	0″ – 8″	Dark, granular clay and sod roots.
B1 horizon	8″ – 18″	Black tough compact clay with weakly fragmental to cloddy structure.
B2 horizon	18″ +	Dark stained brownish grey clay with feebly developed fragmental to granular structure, irregularly tongued and dark stained from above.
Cl horizon	3′ – 4′	Grey-brown clay moderately friable with numerous lime concretions."

A more detailed description and the peculiar tongued condition which occurs in the soils of the Agassiz clays is given by Ellis and Shafer (*3*).

RESULTS

The taking of observations was begun October 21, 1929, and they have been taken each Monday at 9 a.m. since that time with the exception of a period of eleven weeks beginning July 7, 1930. Readings taken daily

would have been more valuable for the upper thermometers, especially during the summer, but owing to the time involved sufficient help was not available. It was found that during the winter when the ground was snow covered, the variations in these upper thermometers were slight even when the air temperature variations were extreme. For short periods on certain occasions during the summer months readings were taken daily and it was found that the surface thermometer, which is covered only with sufficient soil to shut off the direct rays of the sun, responded to changes of air temperature with a lag of about one hour, reaching a temperature approaching 80° F. when the air temperature was near 100° F. On these occasions the 4-inch thermometer lagged behind the surface about three hours with less extreme variations. At a depth of 40 inches the effect of extreme variations in air temperature was scarcely noticeable.

The temperature variation curves for the various depths shown in Figure 1 represent the average of three years' results, *i.e.*, 1931-32-33.

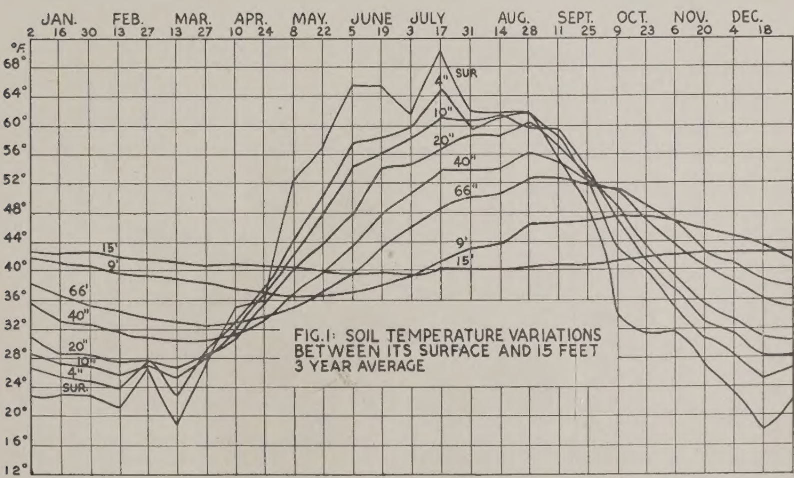

FIGURE 1. Soil temperature variations between its surface and 15 feet; 3 year average.

The curves for each individual year show so little variation in the more important details that the average alone has been included in this report and mention will be made of any point in which a noticeable difference occurred.

What is generally called the "overturn" in soil temperatures is well illustrated in Figure 1. During the winter months the soil temperature increases as the depth increases, the reverse being true during the summer. This overturn during the three years represented by this chart began on March 27th and was completed to a depth of 66 inches by April 27th, 9 feet by May 19th, and 15 feet July 3rd, fourteen weeks being required for the complete overturn. The fall overturn started on August 28th and was complete to a depth of 66 inches October 3rd, 9 feet November 3rd and 15 feet December 24th, requiring a total time of nearly seventeen

weeks. The temperature range for the entire group of curves shows one minimum on April 27th and another on October 3rd. Harrington (*4*) found the corresponding dates at Saskatoon for the year 1923 to be April 16th and October 10th and considered these dates as the days on which the overturn took place.

Probably the most noticeable feature about this set of curves is the decrease in temperature variations as the depth increases, the two upper thermometers varying rapidly with changes in air temperature while the 15-foot thermometer shows a variation of less than four degrees over the entire year. It will also be noticed that the four thermometers in the upper 20 inches reached their lowest temperature on March 13th, while the lowest temperature at 40 inches was registered on March 20th, and 66 inches on March 27th, at 9 feet on May 8th, and at 15 feet on July 3rd, which is only two weeks previous to the date on which the top two thermometers registered their highest temperature. An examination of Tables 1 and 2, which give the minimum and maximum temperatures recorded

TABLE 1.—LOWEST TEMPERATURES RECORDED ON SOIL THERMOMETERS

Depth	1929-30		1930-31		1931-32		1932-33		1933-34	
	Temp., °F.	Date	Temp., °F.	Date	Temp., °F.	Date	Temp., °F.	Date	Temp., °F.	Date
Sur.	19.36	Jan. 20	23.25	Dec. 1	5.44	Mar. 7	12.73	Mar. 20	5.21	Mar. 26
4 in.	20.55	Jan. 27	28.62	Mar. 16	19.12	Mar. 7	19.40	Feb. 13	18.12	Jan. 22
10 in.	22.63	Jan. 27	29.68	Mar. 23	19.62	Mar. 14	22.20	Feb. 20	23.85	Mar. 26
20 in.	25.03	Feb. 3	29.76	Mar. 23	23.50	Mar. 14	23.50	Feb. 20	27.47	Mar. 26
40 in.	29.86	Feb. 17	32.02	Mar. 23	29.08	Mar. 28	27.93	Feb. 20	28.95	Feb. 19
66 in.	31.58	Mar. 24	33.18	Mar. 23	30.85	April 4	31.24	Mar. 6 Mar. 27	31.06	April 9
9 ft.	35.03	May 12	37.24	April 20	35.48	May 23	35.45	May 1	34.94	April 30
15 ft.	39.30	June 23	39.91	July 13	39.02	Aug. 8	38.52	June 26		

TABLE 2.—HIGHEST TEMPERATURES RECORDED ON SOIL THERMOMETERS

Depth	1930		1931		1932		1933	
	Temp., °F.	Date	Temp., °F.	Date	Temp., °F.	Date	Temp., °F.	Date
Sur.	—	—	76.96	June 29	70.19	June 20	81.10	Aug. 7
4 in.	—	—	68.27	June 29	66.61	July 18	69.23	Sept. 4
10 in.	—	—	63.88	June 29	64.23	Aug. 15	62.44	Aug. 7
20 in.	—	—	60.76	Aug. 31	60.37	Aug. 29	60.57	Aug. 28
40 in.	—	—	56.27	Aug. 31	55.72	Sept. 5	57.02	Aug. 28
66 in.	50.61	Sept. 29	54.83	Aug. 31	52.42	Sept. 19	53.37	Aug. 28
9 ft.	46.51	Oct. 6	48.80	Aug. 31	47.59	Oct. 10	47.85	Oct. 9
15 ft.	43.57	Dec. 1	43.51	Dec. 21	42.96	Nov. 14	42.90	Jan. 1/34

annually by each thermometer with the date of occurrence, shows that the lag at a depth of 15 feet is very nearly six months, this thermometer reaching its lowest temperature about the second week in July and its highest temperature on the average about December 15th. The lag at 9 feet is about three months, the highest temperature being reached at

this depth early in October, and the lowest temperature about the middle of May.

Since the temperature range at a depth of 9 feet is about 14° F. and at 15 feet is about 4° F. it is quite probable that at a depth of about 20 feet the temperature of the soil would remain practically constant and beyond this depth the extreme variations which occur in air temperatures in this country—as much as 140° F. between a hot day in summer and a cold day in winter—would have no effect.

The effect of a snow covering on the control of soil temperatures has become evident at many times during this investigation. In Figure 1 the absence of rapid variations in temperature by the upper thermometers during the months of December, January and February as compared with the summer months is very noticeable. A week of mild weather late in February 1932 completely removed the snow cover from the plot in which the thermometers were exposed. Then a drop in air temperatures caused the surface thermometer to register 5.44° F. on March 7th and 6.34° F. March 14th, which was more than 6° F. lower than at any other time during the winter and about 15° F. below the winter average. The air temperature during that week showed a minimum of $-18°$ F. on March 6th and an average minimum for ten days of $-12°$ F., yet there were several days during January and February when the air temperature went below $-30°$ F. with a surface soil temperature of about $+20°$ F.

In Figure 2 the temperatures registered by the surface and 4-inch thermometers at this time are shown graphically and the drop in temperature early in March following the removal of the snow cover is very apparent. This figure shows also another depression, particularly in the surface temperature, on December 21st caused also by the absence of any snow cover. The same thing occurred in March 1933 when the surface thermometer registered a low for the winter of 12.73° F. on March 20th after the protecting snow cover had been removed, this temperature again being several degrees lower than at any other time during the winter with a corresponding air temperature of only 0° F. This would add support to the common belief that the winter killing of plants is very apt to be caused by a too early removal of the snow cover.

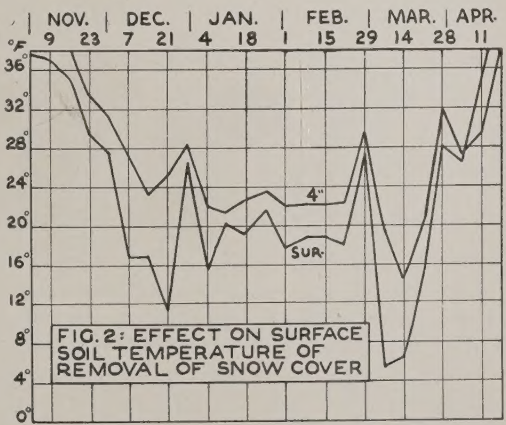

FIGURE 2. Effect on surface soil temperature of removal of snow cover.

Figure 3 shows the date at which each thermometer first recorded a temperature below 32° F. and also shows the rate at which the frost zone

penetrated the soil in the early winter, the depth to which it penetrated, and the rate at which the soil returned to a frost-free condition in the spring. It will be noticed that the soil became frozen from the surface gradually downward usually starting early in November, while in the spring the removal of frost appears to start at the surface and at the lower frost level at about the same time, leaving the last sign of frozen soil late in April or early in May at about the four foot level.

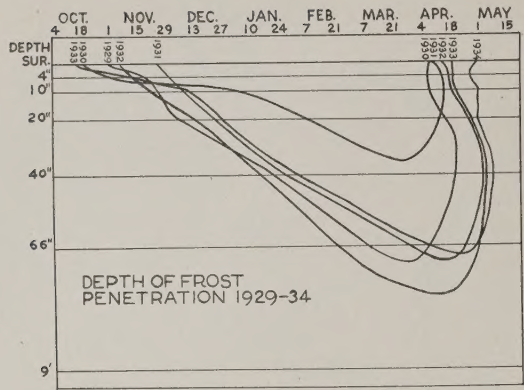

FIGURE 3. Depth of frost penetration 1929-34.

Considerable variation is to be found in both the rate of penetration of frost and the depth to which it penetrates. In 1930 the surface thermometer first showed a temperature below freezing on October 20th and did not rise again above 32° F. until April 6th, 1931. A heavy fall of snow late in October prevented a rapid movement downward of the frost zone, and an unusually mild winter with temperatures which, however, did not remove the snow covering, prevented the frost from reaching a depth greater than about 36 inches. The 40-inch thermometer recorded a low for the winter of 32.02° F. on March 23rd. In 1932 the surface thermometer recorded temperatures below freezing continually from October 31st to April 17th, 1933. The winter was severe, resulting in an almost uniform movement downward of the frost zone at a rate of about 20 inches a month. The 66-inch thermometer recorded a temperature below freezing continually between February 20th and May 1st. The lowest temperature reached at the 9 foot level during this time was 35.45° F. on May 1st, while the 66-inch thermometer was fairly constant between 31.3° F. and 31.7° F. It should be clearly understood that the actual depths to which the frost penetrated could only be estimated from the temperatures recorded by the thermometers situated immediately above and below the lower frost level, but the curves given in Figure 3 should represent with a fair degree of accuracy the frost conditions as they actually existed.

Figure 4 illustrates the comparison between the average air temperature and the average soil temperature at the various depths, April to September, October to March, and the yearly average. Each curve represents an average of all readings taken during the period indicated for three consecutive years, the air temperatures being taken within 200 feet of the location of the soil thermometers, and in a standard instrument shelter. From April to September the average air temperature was 58.4° F., while the average temperature at the surface of the soil was 56.1° F., a difference of only 2.3° F., but as the depth increases this difference rapidly increases until at the 9 foot depth it is 17.81° F. and at

15 feet it is 18.15° F. During the winter season the average air temperature is 15.61° F. and that of the surface soil 25.34° F., a difference of 9.73° F. The winter season difference at 9 feet is 27.09° F. and at 15 feet it is 26.44° F.

When the average temperature at each depth for this three year period was found the result was noteworthy in that all depths were found to have very nearly the same average temperature. The 10-inch thermometer was high with an average of 41.97° F. and the 15-foot thermometer was low with an average of 41.09° F., the average of all depths being 41.58° F. Comparing this with the average air temperature for the same three year period of 36.92° F. it is seen that the average temperature of the soil between the surface and the 15-feet depth is 4.66° F. higher than the average air temperature four feet above the surface. This difference may be partly due to the prevention by the snow cover of a rapid loss of heat during the winter months and to the latent heat of fusion of ice, but is probably due largely to the outward flow of heat from the interior of the earth.

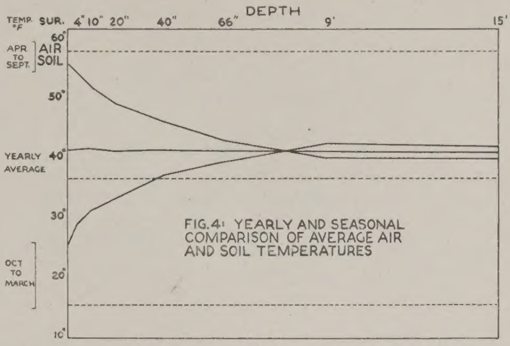

FIGURE 4. Yearly and seasonal comparison of average air and soil temperatures.

It will be noticed that the two seasonal soil temperature curves in Figure 4 cross each other on the curve representing the yearly average at a point corresponding to a depth of 92 inches, separating again beyond that point and approaching the average again as the depth increases. Thus we find, that the soil temperatures from the surface to a depth of 92 inches are higher than the yearly average in summer and lower in winter, while below this depth the soil temperatures are on the average lower during the summer season than the yearly average and higher during the winter season. At that depth of 92 inches the winter season average is the same as that for the summer season.

DISCUSSION

The importance of soil temperature to the agriculturist is evident in the spring of the year when one considers this factor responsible for quick germination of seed and rapid early growth upon which the ultimate success of the crop may so largely depend. Wheat may be sown on adjoining fields on dates differing as much as two or even three weeks in certain years and be harvested at the same time due to the low temperature of the soil in early spring and consequent slow germination and early growth. When time is so often such an important factor in the production of wheat in Western Canada any effort made by the grower to hasten higher soil temperatures in the spring would be of some importance. Man has no control over the meteorological elements which are directly responsible for soil temperatures, but he can at least in some cases encourage the

accumulation of snow in winter and provide for more adequate drainage of surplus water in the early spring.

The time at which cutworm and grasshopper activity begins each spring is determined by soil temperature, and upon this, in turn, will depend the possibility of nature reducing their activities by a period of cold and unfavorable weather. In 1933, soil temperatures were slow to rise with the result that grasshoppers were not seen above the ground in most parts of Saskatchewan until early in June with nothing but summer weather to aid them in their campaign of destruction. In 1934 an early rise in soil temperatures has brought the first grasshoppers above the ground in the same district on May 8th, giving, it would seem, a much greater possibility of a reduction in numbers by unfavorable weather.

ACKNOWLEDGMENTS

The writer wishes to acknowledge with thanks the assistance given by Mr. Charles Gibson, by whom the readings have been taken.

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Résumé

Température du sol à Winnipeg, Manitoba. Wallace A. Thomson, Pense, Saskatchewan.

Huit thermomètres à résistance électrique ont été installés dans une parcelle herbeuse aux profondeurs suivantes: à la surface, 4 pouces, 10 pouces, 20 pouces, 40 pouces, 66 pouces, 9 pieds, 15 pieds, et des lectures ont été prises toutes les semaines au moyen de la méthode Bridge. Le "roulement" des températures, pendant une période de trois ans, s'est commencé le 27 mars et terminé à une profondeur de 66 pouces le 27 avril, de 9 pieds le 19 mai et de 15 pieds le 3 juillet; il a fallu quatorze semaines pour le roulement complet. Le roulement d'automne s'est commencé le 28 août et terminé le 24 décembre, exigeant ainsi dix-sept semaines. Les deux thermomètres les plus près de la surface ont varié rapidement suivant les changements qui se produisaient dans la température de l'air, tandis que la variation enregistrée par le thermomètre placé à 15 pieds n'a pas atteint 4° F. de toute l'année. Le maximum a été atteint en décembre et le minimum au commencement de juillet. Ces variations ont été modifiées considérablement par la couverture de neige, les thermo-

mètres supérieurs enregistrant leur plus basse température aux premiers jours du printemps, après l'enlèvement de la neige. A partir du commencement de novembre généralement, le sol gelait à la surface et la gelée descendait graduellement dans les profondeurs; au printemps la disparition de la gelée commençait à la surface et au niveau le plus bas à peu près vers la même époque, laissant la dernière trace de terre gelée au commencement de mai au niveau de quatre pieds environ. La profondeur de pénétration de la gelée variait beaucoup suivant la nature de la couverture de neige et la rigueur de l'hiver. La profondeur atteinte n'a été que de 36 pouces en 1930-31 tandis qu'elle dépassait 6 pieds en 1932-33. Pendant la saison d'hiver, d'octobre à mars inclusivement, la température moyenne de l'air prise dans un abri régulier pour instruments météorologiques, était de 15.6° F. et celle du sol de surface de 25.34° F. A 9 pieds la température d'hiver était de 42.70° F., et à 15 pieds de 42.05° F.

La température moyenne pendant toute la série de trois ans a été à peu près la même à toutes les profondeurs oscillant seulement entre 41.09° F. et 41.97° F. Pendant la même période de trois ans la température moyenne de l'air a été de 36.92°F. On voit donc que la température moyenne des 15 premiers pieds de sol est de 4.66° F. plus élevée que la température moyenne de l'air prise à quatre pieds de la surface. La température du sol, à partir de la surface jusqu'à une profondeur de 92 pouces, était plus élevée en été et plus basse en hiver que la température moyenne annuelle pour toutes les profondeurs. C'est l'inverse qui s'est produit pour la température au-dessous de cette profondeur tandis qu'à une profondeur de 92 pouces les moyennes pour l'été et l'hiver sont les mêmes.

THE EVALUATION OF THE GERMICIDAL POTENCY OF CHLORINE COMPOUNDS. II. CHLORAMINE-T PRODUCTS

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A number of products in which chlorine in the form of chloramine-T (sodium paratoluene-sulphonchloramide) is the active ingredient are being offered for the sterilization of equipment, etc., in dairy and food plants. This type of sterilizing agent differs from hypochlorite principally in being (1) more stable, especially in the presence of organic matter, and (2) much slower in action. On this latter point the literature indicates considerable disagreement. Dakin, Cohen and Kenyon (*4*) believed its antiseptic action to be four times as great as that of hypochlorite. Tilley (*20*), employing the Rideal-Walker method, reported a significantly higher phenol coefficient for chloramine-T than for sodium hypochlorite against *Staph. aureus.* Myers and Johnson (*16*), using the F.D.A.[2] method, found a chloramine-T product (Santamine) more effective than five hypochlorites of medium to high alkalinity, although inferior to six less alkaline hypochlorites. In a previous paper Johns (*10*), using the F.D.A. method, reported similar results with a chloramine-T product (Wyandotte Sterilizer) containing a large percentage of sodium bicarbonate as "filler." On the other hand, a number of workers (*1*, *2*, *5*, *7*, *8*, *9*, *11*, *13*, *15*, *17*, *18*) have reported chloramine-T solutions as being distinctly inferior to hypochlorites in germicidal speed.

The explanation for these apparently contradictory findings would appear to lie in the property of chloramine-T solutions mentioned above, *i.e.* their much greater stability in the presence of organic matter. Where large quantities of organic matter are added to the test solution as in the usual phenol coefficient methods, the depressive influence upon the germicidal activity of chloramine-T is very much less than in the case of hypochlorites. This is well illustrated by the findings of Myers and Johnson (*16*) and Johns (*10*). The former required a 25% greater concentration of chloramine-T to destroy *Staph. aureus* in bottle rinsing tests than in the F.D.A. technique, while with four hypochlorite products the concentration required in the bottle rinsing tests was from one-fifth to one-tenth of that required in the F.D.A. method. Johns found that where the broth culture inoculum for the F.D.A. method was diluted 1/100 the chloramine-T product appeared distinctly inferior to the six hypochlorite solutions tested concurrently.

Where chlorine solutions are to be used in the presence of considerable amounts of organic matter, such as in wound treatments, etc., it is obviously necessary to employ a testing method in which considerable quantities of organic matter are introduced into the disinfectant solution along with the test organism. On the other hand, where they are intended for use in destroying bacterial growths on the surfaces of *clean* equipment, utensils, etc., the usual phenol coefficient methods give an erroneous impression of the relative germicidal efficiency of the two types of chlorine compounds,

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[2] The method employed by the Food and Drug Administration of the U.S. Department of Agriculture.

and it is necessary to employ testing methods in which the concentration of organic matter is kept at a more appropriate level.

The first paper of this series (*10*) dealt principally with the evaluation of the germicidal potency of hypochlorite products. A number of methods were tried out and their suitability reported upon. One of these, the Burri slant method, was found to be reasonably satisfactory and much freer from "skips" and "misses" than the methods previously employed. Subsequently a simple indicator test for pH and a biological testing method referred to as the "glass slide method" were developed and tested out. It was decided to try out these methods on a smaller series of chloramine-T products, and the results of these tests are reported below.

EXPERIMENTAL

In all the studies reported in this paper, a standardized suspension of *Staphylococcus aureus* (U.S.D.A. No. 209) as used by Myers and Johnson (*16*) was employed. The growth on a Bacto nutrient agar slant (24 hours at 37° C.) was suspended in sterile tap water, filtered through a No. 41 Whatman paper and standardized against a Fuller's earth turbidity standard. All subculture slants, plates, etc., were counted after 2 days incubation at 37° C. All tests were conducted at 20° C. All chlorine concentrations have been calculated on the basis of 1 cc. of 0.1 N. sodium thiosulphate solution representing 0.003546 g. of available chlorine, in order to avoid misunderstandings concerning the use of the term "active chlorine."

1. Burri Slant Method

After 200 p.p.m. solutions of the various products had been prepared and tempered to 20° C. one cc. of suspension of *Staph. aureus* was pipetted into 20 cc. of test solution. This amount of inoculum was sufficient to give a concentration of ten million cells per cc. in the test solution. At suitable intervals ranging between ¼ and 30 minutes, a small loopful (1/3000 cc.) of seeded solution was spread over the surface of a nutrient agar slant and this subsequently incubated. Table 1 contains data from a typical run. In order that the correlation between pH and germicidal speed might be more evident, the six products have been arranged in order of increasing pH (as determined with the glass electrode some weeks after

TABLE 1.—GERMICIDAL POTENCY OF SIX CHLORAMINE-T PRODUCTS (200 P.P.M. AV. CL.) AS MEASURED BY THE BURRI SLANT METHOD. 20° C. JANUARY 19, 1934

Product	pH	Ranking by indicator test	Period of Exposure (minutes)							
			¼	½	1	2	5	10	20	30
Chloramine-T USP	7.31	1	+++	++	140	0	0	0	0	0
Sterichlor	8.61	2	+++	+++	+++	+++	++	+	7	0
XCEM	8.66	2	+++	+++	+++	+++	+++	+	2	0
Wyandotte Sterilizer	8.7	2	+++	+++	+++	+++	+++	+	6	0
Klenocide (liquid)	9.23	3	+++	+++	+++	+++	+++	+++	++	250
Klenocide (powder)	9.92	4	+++	+++	+++	+++	+++	+++	+++	++

N.B.—Density of growth is indicated by the number of plus signs, where the number of colonies was too great to count.

the germicidal tests). In the third column is also given the ranking of the products in order of increasing alkalinity as judged by the indicator test referred to in the following section.

2. Ind'cator Method

In the preceding paper (*10*) details were given of a simple testing method whereby a series of hypochlorites could be arranged in order of germicidal potency. This test was based upon the close correlation between potency and pH, and made use of the fact that different hypochlorite solutions to which a definite quantity of powdered phenolphthalein had been added, assumed various shades of red and magenta depending upon the pH. While the available evidence indicates that the pH plays an equally important role with the chloramine-T solutions (*2*, *13*, *18*) the above technique is not equally satisfactory, since on account of the lower range of pH of these solutions the majority remain colorless. A more satisfactory ranking may be obtained by substituting three drops of 1% alcoholic solution of the same indicator, since the color formed is quite stable and does not fade out as is the case with the hypochlorites. The results obtained with the alcoholic indicator test are included in Table 1.

3. Glass Slide Method

This method, described in detail in the previous paper (*10*), was developed in order to approximate more nearly to the actual conditions under which chlorine solutions are employed in plant practice. The test organisms are present in a film of diluted milk upon the lower half of a microscopic slide, which is gently agitated in the test solution during the period of exposure, then placed in a petri dish and nutrient agar poured to check further action of the chlorine. Since it was natural to expect that with a higher concentration of chlorine the killing time would be greatly reduced, the solutions were tested at a concentration of 2,000 p.p.m. available chlorine in order to avoid the long exposure periods employed with the Burri slant method. Results obtained with the same six chloramine-T products are presented in Table 2.

TABLE 2.—GERMICIDAL POTENCY OF SIX CHLORAMINE-T PRODUCTS (2000 P.P.M. AV. CL.) AS MEASURED BY THE GLASS SLIDE TECHNIQUE. 20° C. MARCH 20, 1934

Product	pH	Period of Exposure (minutes)								
		½		¾		1		2		5
Sterichlor	8.32	**1**		0	0	0	0	0		
XCEM	8.38	**0**		0	0	0	0	0		
Wyandotte Sterilizer	8.50	**70**		5	2	5	0	0		
Chloramine-T U.S.P.	9.18	**99**[1]	**31**[1]	189	65[1]	2[1]				
Klenocide (liquid)	9.20	+		+		+	28[1]	**1**	**1**	0
Klenocide (powder)	9.84	+		+	+	+	+	208	81	**0**

N.B.—Estimated count 35,000 on control plates. The counts in black type mark the shortest exposure period where the average value indicates 99.75% destruction.

[1] Spreaders on these plates probably resulted in unduly low counts.

Effect of Dilution Upon pH and Germicidal Potency

A comparison of the pH values at 200 p.p.m. (Table 1) and at 2,000 p.p.m. (Table 2) reveals that *with five of the products studied the pH is actually greater at 200 p.p.m.* With chloramine-T U.S.P., however, the reverse is true, the pH having declined from 9.18 at 2,000 p.p.m. to 7.33 at 200 p.p.m.[3] This extraordinary behaviour of the five commercial products upon dilution prompted more detailed studies of the influence of dilution upon pH, some results of which are presented in Figure 1. In these studies the autoclaved distilled water used in preparing all solutions was at pH 5.8. Curve A (chloramine-T U.S.P.), is similar in form to a number obtained with commercial hypochlorite solutions similarly diluted with autoclaved distilled water (pH *ca* 6.0). Curve B (XCEM) shows a continual increase in pH on dilution until the concentration of available chlorine is reduced to 25 p.p.m. following which the pH declines sharply as the degree of dilution is increased. It had been observed that this product, as well as several others furnishing similar curves, effervesced strongly upon the addition of acid, and it was suspected that sodium bicarbonate was present as a "filler." Therefore, in order to determine whether sodium bicarbonate played any part in this anomalous behaviour a solution was prepared containing one part of chloramine-T U.S.P. to four parts of sodium bicarbonate and the pH measured at various dilutions. These data are shown in curve C. Finally, the pH values for the bicarbonate itself were obtained and are shown in curve D. The close parallelism between curves B, C and D suggests that sodium bicarbonate is responsible for the peculiar increase in pH on dilution exhibited by the five commercial chloramine-T products.

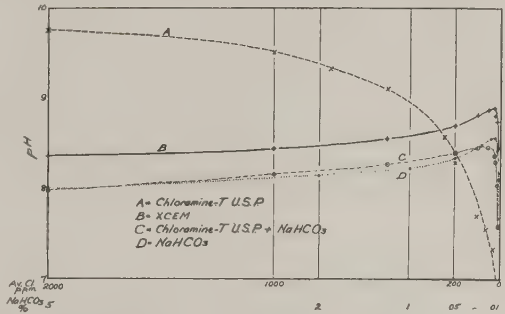

FIGURE 1. Effect of dilution upon the pH values of various solutions.

While the commercial chloramine-T products containing bicarbonate as "filler" may be expected to become steadily less effective from a germicidal standpoint on dilution within the range studied, in the case of the chloramine-T U.S.P., the totally different type of pH-concentration curve suggests that the relationship between concentration and germicidal efficiency may be more complex. Charlton (*2*), in a comprehensive study of the ability of solutions of 4000, 2000 and 1000 p.p.m. of chloramine-T to destroy spores of *Bacillus metiens* (*nov. sp.*) at 25° found that doubling the concentration resulted in a reduction of the killing time to approximately one-half. In the data presented in Tables 1 and 2 of the present paper, it will be observed that at 2000 p.p.m. the U.S.P. product is relatively

[3] It should be noted that the pH values shown in Tables 1 and 2 were obtained from solutions prepared on March 19th, the germicidal tests conducted on the 20th and the pH determination made on the 21st. Subsequent experience has shown that such solutions, especially chloramine-T U.S.P., when held in stoppered volumetric flasks at room temperature, become less alkaline, which doubtless explains the lower values recorded here than will be shown further on.

less effective than three of the five commercial products, while at 200 p.p.m. it proved to be decidedly superior to all five. In the previous paper (*10*) data were presented concerning the effect of dilution upon the germicidal efficiency of an alkaline hypochlorite product (HTH–15). It was found that after declining to a certain point, germicidal activity actually increased upon further dilution. In order to determine whether the same thing might hold true for chloramine-T U.S.P., data on the germicidal efficiency of various concentrations were obtained by the Burri slant, glass slide and plate count methods, and are presented in Figure 2. For convenience in graphical presentation, the end-point has been taken as the destruction of 99.9% of the test organisms for the Burri and plate count methods, and 99.75% for the glass slide method. In the plate count method, the initial number of organisms introduced was reduced to 100,000 per cc. in order that 99.9% reduction would leave a readily countable number of colonies on the plates. In addition, one cc. of sterile N/1 solution of sodium thiosulphate was placed in each petri dish to act as a anti-chlor when the one cc. portion of seeded test solution was transferred to the petri dish at the conclusion of the exposure period.

DISCUSSION

From the data presented, it is evident that the evaluation of the germicidal potency of a series of chloramine-T products is not always a simple matter. For a given concentration of chlorine, any one of the three bacteriological testing methods employed furnishes a satisfactory indication of the relative germicidal speed, while the same holds true for the indicator method. The effect of dilution upon pH is such that the relative efficiency of the commercial products is unlikely to change within the range of concentration studied. With the chloramine-T U.S.P. however, the quite different effect of dilution upon pH results in marked fluctuations in germicidal efficiency as the available chlorine concentration is lowered. Consequently, where the latter is included in a series, its ranking relative to the commercial products will vary according to the concentration at which the tests are conducted. It is therefore necessary that all tests be carried out with solutions of the strength at which they are to be employed in practice.

No definite statement is justifiable concerning the most effective concentration of a chloramine-T product. With the five commercial products studied, it is evident that increasing the concentration within the range at which these products are generally employed results in a definite increase in germicidal potency. On the other hand, the data obtained on chloramine-T U.S.P. with three different testing methods indicate a different state of affairs. While the correspondence between the results from these three methods is by no means exact, there is nevertheless considerable agreement in the general trend of the curves. All three indicate a decline in efficiency to a point in the neighborhood of 1000 p.p.m. followed by a definite increase in efficiency to a point at approximately 200 p.p.m. Beyond this the results are less concordant, the Burri slant method showing a decline on further dilution which is less definite and pronounced for the plating method. Unfortunately, the tests with the glass slide method were not continued below 200 p.p.m.

It will also be observed that the slope of the curve for concentrations in excess of 1000 p.p.m. is definitely steeper for the Burri slant and glass slide methods than for the plating method. A likely explanation for this discrepancy lies in the fact that with the first two methods no antichlor treatment was employed, and the small amount of strong chloramine-T solution carried over in subculturing continued to act upon some of the cells after transfer to the slant or petri dish. An examination of the data obtained with the glass slide method, particularly comparing 4,000 and 2,000 p.p.m. with the lower concentrations, lends support to this hypothesis.

It should be borne in mind that the results reported in this paper deal with the effect of dilution with autoclaved distilled water, the reaction of which was in the vicinity of pH 6.0. With a more alkaline water, the effect of dilution upon the products which contain bicarbonate would presumably be much the same, while with the U.S.P. product, it would doubtless affect the steepness of the pH-concentration curve and possibly the relative germicidal potency at different concentrations.

The peculiar fluctuations in germicidal efficiency of chloramine-T U.S.P. on dilution as exhibited in Figure 2 require an explanation. In the previous paper (*10*), the variation in potency of a hypochlorite solution on dilution was noted and an explanation offered. This explanation was based upon the fact that hypochlorous acid is generally conceded to be the germicidally active constituent and that the ratio of this acid to sodium hypochlorite is a function of the pH of the solution. Calculation of the concentration of hypochlorous acid present at various concentrations of total available chlorine between 25 and 1 p.p.m. afforded data supporting the above explanation. The question naturally arises as to whether a similar hypothesis would serve to explain the anomalous behaviour of chloramine-T U.S.P. In the first place it seems possible that traces of hypochlorous acid may be formed in chloramine-T solution. Charlton (*2*) states, "Whether chloramine-T exerts a germicidal action by means of HOCl or in some other way, cannot be definitely stated." Süpfle (*19*) quotes Hailer (*6*) to the effect that chloramine-T in aqueous solution forms sodium hypochlorite and p-toluenesulphonamide. This appears to be not unreasonable since chloramine-T is prepared by dissolving p-toluenesulphonamide in sodium hypochlorite (*4*) and we may therefore expect hypochlorous acid to be formed from the chloramine-T, although doubtless in very much smaller amounts than in a hypochlorite solution of equivalent chlorine strength and pH.

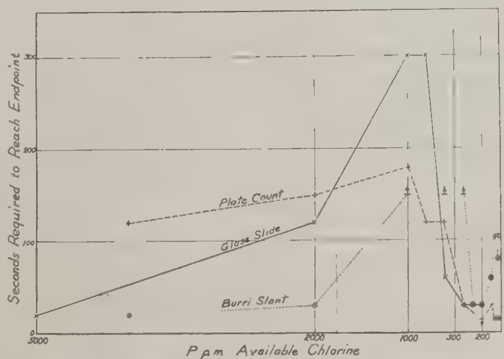

FIGURE 2. Effect of dilution upon germicidal efficiency of chloramine—T U.S.P., as judged by three different testing methods.

In order to measure the quantity of hypochlorite present in water containing various chlorine and chlorine-ammonia compounds, Holwerda (*7*) employed the methyl orange titration method developed by Massink (*14*). This suggested the possibility of employing this reaction to discover whether or not hypochlorite is present in a chloramine-T solution. This test is apparently intended for the estimation of very small quantities of hypochlorite, for with a 20 p.p.m. solution of chloramine-T no definite end-point could be obtained. However, tests on 1 p.p.m. solution were more satisfactory, 0.4 cc. of methyl orange solution being required per 100 cc. as compared with 1.89 cc. per 100 cc. of a 1 p.p.m. hypochlorite solution of low alkalinity (HTH). If this reaction is specific for chlorine in the form of hypochlorite, as Besemann claims (*1*), then the above results indicate that hypochlorous acid is present to some slight extent in a dilute solution of chloramine-T.

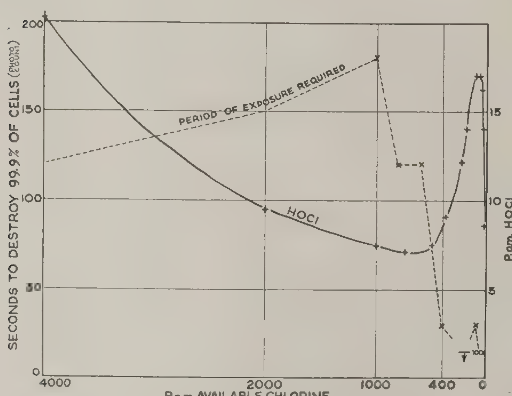

FIGURE 3. pH and assumed HOCI concentration of solutions of chloramine—T U.S.P., containing varying amounts of available chlorine.

Charlton (*2*) as a result of his investigations concluded that "in the absence of added organic matter it requires about 100 times as much available chlorine in the form of Chloramine-T as in the form of hypochlorite to destroy vegetative cells." If therefore we assume that the germicidal activity of a chloramine-T solution is dependent upon the amount of hypochlorous acid present, and that the latter is present in 1/100 of the concentration that would be expected in a hypochlorite solution of equivalent chlorine strength and pH, we may calculate by means of the Henderson-Hasselbalch equation, $pH = pKa + \log salt/acid$, the assumed concentration of hypochlorous acid for various concentrations of chloramine-T. This has been done and the results are plotted in Figure 3 together with the pH-concentration curve. In order to facilitate comparison between germicidal efficiency and hypochlorous acid concentration the curve for the assumed concentration of hypochlorous acid has been similarly plotted along with the end-point data obtained with the plate count method (Figure 4). It will be observed that a substantial agreement exists between the assumed concentration of hypochlorous acid as calculated and the germicidal potency, indicating that the tentative explanation offered above may be fairly close to the truth.

It should be pointed out that the assumed concentrations of hypochlorous acid as calculated above are very much higher than those calculated for sodium hypochlorite solutions in the previous paper. For the latter, the values were 0.013 for 25 p.p.m., 0.014 for 10 p.p.m. and 0.03 for 2 p.p.m. available chlorine. The latter concentration of sodium hypo-

chlorite was approximately equal in effectiveness to 400 p.p.m. of chloramine-T U.S.P. solution, for which the calculated concentration of hypochlorous acid, based upon Charlton's estimate is 9 p.p.m. It appears therefore that if hypochlorous acid is actually present, the actual concentration in a given content of available chlorine would be much less than 1/100 of that existing in a sodium hypochlorite solution of equivalent pH and available chlorine concentration.

With regard to the effect of dilution upon the pH values of chloramine-T products containing bicarbonate (Figure 1), such an unexpected finding as an increase in alkalinity on dilution of a slightly alkaline product with distilled water of pH *ca* 6.0 suggested that this effect might be peculiar to the use of the glass electrode. However, similar curves have been obtained with sodium bicarbonate solutions tested out colorimetrically with thymol blue and phenol red, and electrometrically with the quinhydrone electrode. Furthermore, solutions prepared from different lots of sodium bicarbonate (Merck's and Baker's) and distilled water from different laboratories have all shown the same tendency to increase in pH on dilution, and a similar effect was observed with potassium bicarbonate, indicating that the explanation must be sought elsewhere.

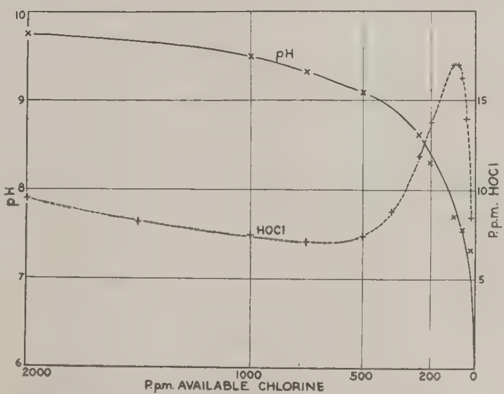

FIGURE 4. Relation between assumed concentration of HOCl and germicidal speed of solutions of chloramine-T U.S.P. containing varying amounts of available chlorine.

It is of interest to record here that Lepper and Martin (*12*) in studying the discrepancy between colorimetric and electrometric (hydrogen electrode) determinations of the pH of blood serum, present data concerning the pH of solutions of 0.02 M sodium bicarbonate containing decreasing amounts of sodium chloride. As the concentration of sodium decreases, the pH increases, although the concentration of bicarbonate is uniform throughout. No data are recorded concerning bicarbonate solutions in the absence of sodium chloride. These workers believed this anomalous behaviour to be due to the concentration of sodium ion and its influence on dissociation in accordance with the mass law. Cullen (*3*), in studying the pH of blood plasma, noted that serum showed a continuous increase in alkalinity when diluted with 0.9% sodium chloride solution up to a dilution of fifteen to twenty-fold, and further stated, "The use of salt solution instead of water as a plasma diluent is necessary because the curve is . . . . steeper with water than with saline solution . . . ." Cullen made no attempt to explain this peculiar effect of dilution, nor will any be made here, such investigations being beyond the scope of the present studies. The effect is of interest primarily because of the fact that

commercial chloramine-T products containing bicarbonate, unlike the U.S.P. product, become steadily less effective on dilution over the range studied.

SUMMARY

Three bacteriological methods and one chemical (colorimetric) method have proven useful in evaluating the relative germicidal efficiency of chloramine-T products in the absence of large amounts of organic matter.

The effect of dilution on the pH of the commercial products studied was most unexpected, the solutions becoming *more alkaline* on dilution with distilled water of slightly acid reaction. Since sodium bicarbonate, known to be present as a filler in commercial products, behaves similarly, this anomalous increase in alkalinity on dilution may be attributed to the presence of bicarbonate. Within the range of 2,000 to 25 p.p.m. available chlorine, these products may be expected to decline in germicidal activity on dilution.

Solutions of chloramine-T U.S.P. on the other hand decrease in alkalinity on dilution, furnishing a pH-concentration curve similar to that for a hypochlorite solution. The germicidal potency, however, does not decline uniformly on dilution; below 1,000 p.p.m. the activity increases to a point around 200 p.p.m., falling off again beyond this. On the assumption that chloramine-T yields a trace of hypochlorous acid in solution the assumed concentrations have been calculated from pH data and are found to be in substantial agreement with the fluctuating germicidal potency.

Acknowledgments

The writer wishes to express his thanks to Dr. A. G. Lochhead, Dominion Agricultural Bacteriologist, for advice upon certain phases of the work, and to Messrs. A. H. Jones, B.S.A., and G. B. Landerkin, B.S.A., for assistance in connection with the germicidal testing.

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Résumé

L'évaluation de la puissance germicide des composés de chlore. II. Produits de chloramine-T. C. K. Johns, ferme expérimentale centrale, Ottawa, Ont.

Trois moyens bactériologiques et un moyen chimique (colorimétrique) se sont montrés utiles pour évaluer la capacité germicide relative des produits de chloramine-T (ou Tochlorine) en l'absence de grandes quantités de matières organiques. L'effet de la dilution sur le pH des produits commerciaux à l'étude a été des plus inattendus. Les solutions devenaient *plus alcalines* lorsqu'elles étaient diluées avec de l'eau distillée ayant une réaction légèrement acide. Comme le bicarbonate de soude que l'on sait être présent comme substance de remplissage dans les produits commerciaux se comporte de la même façon, cette augmentation anormale de l'alcalinité par dilution peut être attribuée à la présence du bicarbonate. On peut s'attendre à voir la faculté germicide de ces produits diminuer après dilution dans la proportion de 2,000 à 25 p.p.m. de chlore utile. Par contre, l'alcalinité des solutions de chloramine-T U.S.P., diminue après dilution, fournissant une courbe de concentration du pH semblable à celle d'une solution d'hypochlorite. Cependant la puissance germicide ne diminue pas uniformément après dilution; au-dessous de 1,000 p.p.m. l'activité augmente jusqu'à un point touchant 200 p.p.m. et diminue à nouveau lorsque ce point est dépassé. Se basant sur la supposition que la tochlorine (Chloramine-T) rend une trace d'acide hypochloreux en solution, l'auteur a calculé les concentrations supposées d'après les données du pH et a trouvé qu'elles sont conformes à la puissance germicide fluctuante.

STUDIES ON THE CONTROL OF ROOT ROT DISEASES OF CEREALS CAUSED BY *FUSARIUM CULMORUM* (W. G. SM.) SACC. AND *HELMINTHOSPORIUM SATIVUM* P., K., AND B.

I. FIELD METHODS WITH ROOT ROT DISEASES.[1]

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INTRODUCTION

Root rot diseases of cereals caused by species of *Helminthosporium* and *Fusarium* are wide-spread and destructive in the three prairie provinces of Canada. In certain localities they are a limiting factor in the production of cereals *(4)*. The production of resistant varieties of cereals by breeding offers the most promising method of controlling these diseases. Other control measures aim at the destruction of the fungi on the seed and in the soil.

To differentiate between varieties of cereals for resistance and susceptibility to root rots, and to determine the effectiveness of various seed and soil treatments for the control of these diseases, it is necessary to produce artificially annual attacks of epidemic severity. In the field it is difficult to do this. The problem involves not only the development of practical and efficient devices to induce disease attacks, but the development of reliable methods of recording and analyzing root rot experimental data. This paper presents the results of three years' experiments designed to give effective and practical field methods of insuring positive attacks with the common cereal root-rotting fungi *Fusarium culmorum* (W. G. Sm.) Sacc. and *Helminthosporium sativum* P., K., and B.

It may be mentioned in passing that species of *Fusarium* and *Helminthosporium* occur together in the soil and are frequently isolated from the same diseased portion of the underground plant parts. Consequently, in this paper, the term "root rot" is used to designate a diseased condition of the base and roots of the plant. The term thus includes the various manifestations—seedling blight, foot-rot or crown-rot, and root-rot—caused by attacks of *F. culmorum* and *H. sativum*.

The general problem of root rot diseases of small grains has received considerable attention in many countries. Bolley *(1)*, Cordley *(3)*, Stevens *(18)*, Henry *(9)*, McKinney *(12)*, Christensen *(2)*, Simmonds *(16)*, Greaney and Bailey *(8)*, and others, have shown the great economic importance of these diseases in Canada and the United States. The literature on the subject has been thoroughly reviewed by these workers.

EXPERIMENTAL METHODS

The land on which the field experiments were conducted each year consisted of well-tilled, summerfallowed clay soil at Winnipeg, Manitoba.

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It had been cropped in a uniform manner the previous year, and cultural conditions during each growing season were uniform throughout.

Plan of Experiments.—Five different methods of introducing *F. culmorum* and *H. sativum* into the soil were tested in 1931 and 1932 on three varieties of wheat, one of oats, and one of barley. The Latin Square arrangement of blocks was used for the varieties, and eleven plots, representing five treatments with each organism and an untreated check, were randomized within each block. Each plot consisted of two rod-rows, one in which the seeds were spaced in the row, 100 seeds per row, and the other in which a weighed amount of seed, according to the variety, was sown by hand and distributed evenly along the row. The former row was used for estimating the amount of disease in each plot, while the latter furnished the yield data. The rows were planted one foot apart, and the complete experiment consisted of 175 plots.

A second experiment was made in 1932 in which five different methods of artificially inducing root rot attacks were tested with each of the fungi, *H. sativum* and *F. culmorum*, on Marquis wheat. A Randomized Block arrangement of plots was used, incorporating each treatment with each organism in each block. There were six blocks in this experiment.

Two distinct experiments were made in 1933, one with the fungus *F. culmorum* and another with *H. sativum*. In each experiment eight different methods of introducing the fungus into the soil were studied. The Randomized Block plan of plot experiment was employed, and the blocks were adequately replicated. Marquis wheat was used in both experiments.

Varieties and Organisms.—Marquis, Mindum and Marquillo wheat, Banner oats, and Canadian Thorpe barley were the varieties used in 1931 and 1932. The seed was obtained from pure line material and selected for uniformity in size and plumpness, but it was not surface-sterilized. In 1933, Marquis only was used. In that year the seed, in order to insure a positive attack with root-rotting fungi, was injured slightly by scarifying with sand-paper.

The strain of *Fusarium* used in the field experiments was isolated originally in 1930 from a rotted crown of Marquis wheat, and was identified by Dr. W. L. Gordon, Dominion Rust Research Laboratory, Winnipeg, as *Fusarium culmorum* (W. G. Sm.) Sacc. The strain of *Helminthosporium sativum P.*, K., and B. used was obtained in 1930 from diseased roots of barley. Repeated greenhouse tests demonstrated that both fungi were highly pathogenic on wheat, barley and rye. The strain of *F. culmorum* studied was distinctly pathogenic on oats.

Methods of Infesting Soil.—Two principal methods were used to introduce *H. sativum* and *F. culmorum* into the soil. The first method consisted of applying a solid medium, overgrown with the fungus to be tested, to the soil at seed level. Adding spores of the fungus to the seed before it was sown constituted the second method.

As Sallans *(14)* has pointed out, oat-hull mash provides an excellent medium for the development of *H. sativum*. Simmonds *(16)* found finely-ground oat hulls to be an excellent medium on which to grow *F. culmorum*. For the purpose of the present studies the fungi were grown on sterilized oat-hull mash in one-half gallon jars. This medium, when

completely overgrown with mycelium bearing numerous spores of the fungus (oat-hull inoculum), was applied in various amounts to the soil. Another type of solid medium used for introducing root-rotting fungi into field soil consisted of one part oat-hull inoculum to nine parts of autoclaved soil, by volume. This mixture (soil inoculum) was incubated for two weeks and then applied at the rate of 600 cc. per rod row. The solid media were applied at seeding time and distributed uniformly at seed level in each row.

The method of applying spore suspensions to seed has been used with considerable success by Stakman *(17)*, McKinney *(11)*, and Sallans *(14)*, to introduce *H. sativum* into the soil. Simmonds *(16)*, in some greenhouse tests, produced foot-rot and seedling blight of oats by drying spore suspensions of *F. culmorum* on the seed. Wherever this method was used in the present field studies the seed was inoculated with a heavy suspension of conidia of the fungus, dried rapidly, and sown a few hours later.

The solid-medium and spore-suspension methods of introducing pathogenic fungi into the soil have been tested singly, and in various combinations.

Recording Disease Infection and Yield Data.—Fifteen days after planting, germination counts were taken on the spaced-seed row of each plot in the experiment. The plots were under observation continuously and the development of the disease was observed on the plants in the control plots. Approximately ten days before harvest, when the crop was still green, the plants in the spaced-row of each plot were lifted, counted, and examined individually, and the severity of infection on the basal parts recorded. A modification of the method described by McKinney *(11)* was used in recording the extent of disease. Each plant was given a numerical rating based on the degree of infection, and the final disease rating for the plants grown in a given plot was computed from the sum of all the numerical ratings. The numerical ratings used in this study are described in Table 1.

Table 1.—Numerical classes used in rating healthy and diseased cereal plants grown in field soil infested with root-rotting fungi

Class	Extent of disease on underground parts	Numerical rating
1	No infection	0
2	Small lesions on sheaths, coleoptile or roots	1
3	Distinct lesions on underground parts; with severe rotting of coleoptile	2
4	Numerous large lesions on roots and basal parts of plant	3
5	Plant stunted, with complete rotting of coleoptile and sheaths. Roots badly rotted; and culms dead	4
6	Dead plant. Plant fails to emerge, or is killed before maturity	5

$$\text{Disease Rating} = \frac{\text{Sum of numerical ratings x 100}}{\text{Total number of seeds planted x 5}}$$

The result is then a comparative infection rating for each treatment. The results from all plants grown in a given experiment were compared on a basis of factors derived according to the above method for each treatment.

In determining the disease rating it was assumed that all seeds planted in the spaced-row of each plot were capable of germination. Repeated germination tests indicated that from 96 to 100% of the seed used was viable. It is important to point out, however, that, in field tests with root rot diseases of cereals, it is often difficult to determine whether non-emergence is due to parasitic attack or to poor germination of the seed. Furthermore, it is impossible to prevent contamination from common soil-inhabiting organisms.

The yield data of each treatment were secured by harvesting and threshing separately the second rod row of each plot.

According to the methods described above, two complete sets of data (disease rating and yield) were obtained for a given treatment in each experiment. To obtain information as to the significance of the differences observed between different methods of introducing pathogenic fungi into the soil, the experimental data were treated by the "Analysis of Variance" method and Z test (Fisher *(6)*). The method of analyzing the data cannot be described here in detail, and reference should be made to Fisher *(6)*, Fisher and Wishart *(5)*, and Goulden *(7)*.

ANALYSIS OF DATA

Relation Between Root Rot Disease Rating and Yield

Accurate measurement of the intensity of the diseases caused by root-rotting fungi on cereals is essential in studying these diseases. Without measurement it is impossible to decide if the amount of disease on treated plots is greater or less than on untreated ones, or to estimate accurately the degree of susceptibility and resistance, or to estimate the economic importance of root rot diseases. As cereal crops are grown for the amount of grain produced, it is essential that any measurement of root rot disease intensity should bear relation to the yield of grain.

In experimental plot work detailed measurements are possible, the chief deterrent from making them being the time and labour involved. The requirement is a simple and reliable method that can be standardized for measuring the amount of disease in different experiments and in different years. The method adopted in the present experiments is described above. Since the classification involved requires personal judgment it is most essential that one observer make all the measurements on any given experiment. If two or more observers have to make measurements they must work by some simple numerical scale and frequently check their observations.

The importance of accurate measurement in dealing with the root rot problem cannot be over-emphasized. The obtaining of such data requires a very careful arrangement of experimental plots with considerable replication, in other words, the employment of modern methods of field experimentation. Owing to the complexity of the root rot problem and the nature of the difficulties involved, the degree of replication and the size and number of samples to be taken, if statistically significant results are to be obtained, are much larger than have usually been taken in the past.

In the final analysis of the results of each experiment, in order to discover whether or not the disease rating constituted a reliable method of recording the amount of injury caused by *H. sativum* and *F. culmorum* on wheat, disease ratings and the yields of individual plots were correlated. The significance of the correlation coefficients so obtained was determined according to the method described by Fisher *(6)*. Correlation coefficients for disease rating and yield in these experiments, and the computed values of t, are given in Table 2.

TABLE 2.—CORRELATION COEFFICIENTS FOR ROOT ROT DISEASE RATING IN RELATION TO THE YIELD OF WHEAT. RESULTS OF FIELD EXPERIMENTS WITH MARQUIS AND MINDUM WHEAT

Year	Variety	Organisms	Correlation coefficient	t*
1931	Marquis	*H. sativum* and *F. culmorum*	−0.32	2.48
	Mindum	*H. sativum* and *F. culmorum*	−0.52	4.47
1932	Marquis I	*H. sativum* and *F. culmorum*	−0.39	3.05
	Mindum	*H. sativum* and *F. culmorum*	−0.63	5.93
	Marquis II	*H. sativum* and *F. culmorum*	−0.69	6.22
1933	Marquis.	*H. sativum*	−0.62	6.05
	Marquis	*F. culmorum*	−0.80	10.34

*5% point = 2·04 1% point = 2·75

The significant negative correlations given in Table 2 indicate that increases in the amount of root rot, as expressed by the disease rating, result in decreases in yield. In all experiments the correlations were highly significant. The results of the analysis establish the fact that the disease rating is closely related to the yield, and hence constitutes an accurate measurement of the amount of root rot caused by *H. sativum* and *F. culmorum* on wheat under field conditions.

As no marked seasonal differences occurred at Winnipeg during the growing periods of 1931, 1932 and 1933, it may be assumed that the positive attacks of root rot obtained in 1933 were brought about by improvements in field technique. Undoubtedly the high degree of association between disease rating and yield (−0.80) obtained in that year, in plots infested with *F. culmorum*, was due, in part at least, to the employment of scarified seed. Machacek and Greaney *(13)* have demonstrated that the use of mechanically injured seed promotes the development of root rot caused by *F. culmorum* on cereals, thereby retarding the growth of the plants and decreasing yield.

The results of the analysis in Table 2 show that root rot diseases caused by *H. sativum* and *F. culmorum* have a marked detrimental effect on the yield of wheat.

Results with *Helminthosporium Sativum*

Examination of the results of experiments with *H. sativum* (Table 4) indicated strongly that a real effect due to different methods of infesting soil was being studied. In order to verify the results, a thorough examination of the data was essential. Fisher's analysis of variance method has

been utilized for this purpose. This method for the analysis of Randomized Block experiments permits an evaluation of the significance of the experiment as a whole, as well as of the individual treatments. Table 3 gives the analysis of variance of a modified Randomized Block experiment with *H. sativum*, and illustrates the method of analysis utilized in all field experiments reported in this paper.

TABLE 3.—COMPLETE ANALYSIS OF VARIANCE FOR DISEASE RATING AND YIELD OF THE 1933 *Helminthosporium* EXPERIMENT

Disease Rating

Source of variance	Degrees of freedom	Sum of squares	Variance	Z	5 per cent point
Units	2	61.67	30.83		
Rows	3	118.38	39.46		
Columns	3	88.87	29.62		
Treatments	9	1,585.62	176.18	1.1430	0.3726
Error	42	752.52	17.91		
Total	59	2,607.06			

Yield

Source of variance	Degrees of freedom	Sum of squares	Variance	Z	5 per cent point
Units	2	304.43	152.21		
Rows	3	37.60	12.53		
Columns	3	10.60	3.53		
Treatments	9	314.60	34.95	1.0876	0.3726
Error	42	166.92	3.97		
Total	59	834.15			

If no treatment differences existed the variances estimated from treatments (Table 3) would be expected to differ from the error variances only by an amount which might be obtained by chance. In this experiment the variances due to treatments are much greater than the variances due to error. The significance of the results, however, is assessed by the "Z" test in which the variances due to any known cause is compared with the variance due to error. The 5% probability value, which is the value which Z must attain to assure a probability of 20 to 1 against the result obtained being merely due to chance, was used in these studies. The values of Z for soil treatments are given in Table 3.

The statistical analysis clearly establishes the significance of soil treatment differences and a more detailed examination of the results can be made. The standard errors of the experiment were calculated directly from the variance tables, and the standard errors of the means of treatments are given in Table 4.

In the present studies it is considered that, to be significant, a minimum difference between any two treatments should be three times the standard error. For an easy inspection of the results and their significance, all significant values in Tables 4 and 5 are given in heavy type.

TABLE 4.—RELATIVE EFFECT OF DIFFERENT METHODS OF INFESTING FIELD PLOTS WITH THE FUNGUS *Helminthosporium sativum* ON THE AMOUNT OF ROOT ROT INFECTION, AND ON THE CONSEQUENT YIELD OF CEREAL VARIETIES IN 1931, 1932 AND 1933, AT WINNIPEG, MAN.

Year	Kind and amount of inoculum per rod row										
	Oat-hull (grms.)				Soil 600 cc.	Seed (spore susp.)	Seed (s.s.) plus soil (600 cc.)	Seed (s.s.) plus oat-hull (120 grms.)	Seed (s.s.) plus soil, plus oat-hull	Con-trol	Standard error of means of treat-ments
	40	80	120	160							
	Disease Rating										
1931	60.8	**62.8**	**62.8**	**66.2**	59.0					59.0	1.10*
1932 I		60.9	59.0	59.5	59.9	**62.2**				57.8	1.31
1932 II			66.0		68.0	64.2	68.0	**76.5**		68.0	2.40
1933	**72.0**	**72.7**	**79.3**		66.5	**76.4**	**73.3**	**82.4**	**77.8**	66.2	1.73
	Yield (Bushels per acre)										
1931	34.2	34.5	32.7	32.9	35.5					36.0	
1932 I		43.1	41.8	37.6	43.9	40.4				42.7	1.97
1932 II			14.2		13.8	17.6	17.4	16.5		16.7	2.29
1933	21.8	**20.0**	**20.1**		24.1	**19.0**	**20.0**	**16.4**	**18.0**	22.8	0.81

*To be significant the differences between means of treatments must exceed $2\sqrt{2 \times 1.10} = 2.96$. Significant values between soil treatments and controls are given in bold type.

To economize space the results of the three years' experiments with *H. sativum* are summarized in Table 4. From this table it will be observed that although significant differences in disease rating occur, thus indicating the effectiveness of individual methods of introducing the fungus into the soil, these are not always accompanied by significant yield differences. For the purpose of the present study the presence of statistically significant values for disease rating is only of relative value. It is considered that significant yield differences are essential in order to determine the effectiveness of any artificial method of inducing heavy root rot infection on cereals in the field.

From the data in Table 4 it will be observed that applications of oat-hull inoculum, or soil inoculum, to field soil at seed level, failed to increase the amount of root rot on cereals. In 1933 the highest degree of infection was obtained by using inoculated seed and applying oat-hull inoculum. The employment of these methods resulted in a statistically significant reduction in yield. The seed spore-suspension method gave satisfactory results in 1933, but it was not so effective in 1931 and 1932.

Sallans *(14)*, in 1930, obtained heavy field infections by inoculating wheat seed with a spore-suspension of *H. sativum*. He reported that the severity of infection was influenced by incubating the treated seed for from 18 to 27 hours at 24°C. It is possible, therefore, that a higher degree of infection with *H. sativum* than was obtained in the field experiments here reported may be achieved by standardizing the method of seed inoculation. Further studies are required to determine an effective and practical method of infesting plots of wheat and barley with *H. sativum*.

Results with *Fusarium Culmorum*

The results of three years of field experiments designed to given an effective and practical method of inducing positive attacks of root rot caused by *F. culmorum* on cereals, are presented in Table 5.

TABLE 5.—RELATIVE EFFECT OF DIFFERENT METHODS OF INFESTING FIELD PLOTS WITH THE FUNGUS *Fusarium culmorum* ON THE AMOUNT OF ROOT ROT INFECTION, AND ON THE CONSEQUENT YIELD OF CEREAL VARIETIES IN 1931, 1932 AND 1933, AT WINNIPEG, MAN.

Year	Kind and amount of inoculum per rod row											
	Oat-hull (grms.)				Soil 600 cc.	Seed (spore susp.)	Seed (s.s.) plus soil (600 cc.)	Seed (s.s.) plus oat-hull (120 grms.)	Seed (s.s.) plus soil, plus oat-hull	Control	Standard error of means of treatments
	40	80	120	160							
Disease Rating*											
1931	62.1	**65.2**	**65.6**	**67.6**	**68.9**					59.6	1.10
1932 I		**63.6**	**63.2**	**66.4**	**65.5**	**80.1**				57.8	1.31
1932 II			68.0		**70.0**	**83.2**	**87.5**	**87.2**		62.2	2.40
1933	68.2	**74.4**	**76.1**		**83.8**	**97.3**	**96.4**	**96.8**	**97.4**	63.1	2.04
Yield (Bushels per acre)*											
1931	33.1	34.2	34.2	32.8	29.6					36.0	
1932 I		39.3	38.1	37.1	44.8	**29.1**				42.7	1.97
1932 II			11.9		16.3	8.8	**4.9**	**7 6**		16.7	2.29
1933	18.9	18.5	19.4		**16.6**	**6.3**	**6.6**	**6.2**	7.2	21.8	1.38

*Statistically significant values between soil treatments and controls are given in bold type.

From these data it is evident that although some of the oat-hull inoculum treatments were effective in that their application resulted in a higher degree of root rot infection, none of them gave significant responses in yield. When used alone soil inoculum (one part oat-hull inoculum to nine parts soil), applied at the rate of 600 cc. per rod row, gave very satisfactory results in 1933, but this treatment did not reduce yield in other years.

The most effective method employed to induce *Fusarium* root rot attacks in the field was the application of spores of the fungus to the seed before sowing. The employment of this method increased the amount of root rot, and, in 1932 and 1933, resulted in decreased yields. In these years a combination of two methods, namely, dipping the seed in a suspension of conidia before sowing and applying soil inoculum at the rate of 600 cc. per rod row, markedly increased the amount of root rot and decreased yield. In general, however, the effect on the amount of root rot infection and on the yield, of employing a combination of two or three methods to introduce *F. culmorum* into the soil, was not more marked than when the spore-suspension method alone was used.

From Table 5 it is apparent that the spore-suspension method is a very effective means of inducing positive attacks of root rot caused by *F. culmorum*. Moreover, it constitutes a practical method of artificially creating a destructive attack of this disease on cereals. A vigourously

sporulating strain of *F. culmorum* gave positive infection results in these experiments, but whether or not similar results could be obtained on cereal plants with other parasitic species of *Fusarium* is a problem requiring further investigation.

The practical possibilities of the seed spore-suspension method of producing artificial epidemics of root rot on wheat with the fungus *F. culmorum* was demonstrated in 1933. In that year a field experiment was made to compare the effectiveness of four fungicidal seed treatments for the control of root rot of wheat. This experiment was designed also to determine the effect on root rot development of two different methods of introducing the fungus into the soil.

A modified Randonized Block arrangement of plots was used, incorporating four seed treatments and three soil treatments. Seed and soil treatments were properly randomized in each block, and the complete experiment consisted of six blocks containing 72 plots. Each plot was composed of two rod rows, one in which the seed was spaced, 100 seeds per row, and the other containing 18 gms. of Mindum seed sown by hand and distributed uniformly along the row. The former row furnished the disease-rating and the latter the yield data.

One series of plots in this experiment was planted with Mindum wheat which had been previously inoculated with spores of *F. culmorum*. In another series inoculated seed was planted in soil to which 600 cc. of soil inoculum, prepared as described previously, was applied at seed level in each rod row. A third series of plots was not infested by artificial methods and served as the control. The results of the analysis of variance for disease rating and yield of this experiment are given in Table 6.

TABLE 6.—COMPLETE ANALYSIS OF VARIANCE FOR DISEASE RATING AND YIELD OF AN EXPERIMENT TO DETERMINE THE EFFECT OF SEED TREATMENTS AND SOIL TREATMENTS ON THE DEVELOPMENT OF ROOT ROT CAUSED BY *Fusarium culmorum*

Source of variance	Degrees of freedom	Sum of squares	Variance	Z	5 per cent point
Disease Rating					
Controlled error	8	1,512.81	189.10		
Seed treatments	3	422.26	140.75	0.6536	0.5117
Soil treatments	2	3,774.06	1,887.03	1.9516	0.5777
Seed treatments v. soil treatments	6	1,420.20	236.70		
Error	52	2,026.07	38.96		
Total	71	9,155.40			
Yield					
Controlled error	8	3,232.29	404.04		
Seed treatments	3	52.60	17.53		
Soil treatments	2	422.39	211.19	1.1116	0.5777
Seed treatments v. soil treatments	6	413.36	68.90		
Error	52	1,189.07	22.86		
Total	71	5,309.71			

The results of the statistical analysis of the data establish that, although there is a significant value for disease rating between the various fungicidal seed treatments tested, the results for yield are not significant, and hence the experiment may be assumed to be unimportant in so far as determining the efficiency of seed treatments for the control of *Fusarium* root rot of wheat. On the other hand, the results of the analysis of soil treatments in Table 6 show that the differences, both in disease rating and yield, due to methods of introducing *F. culmorum* into the soil, are significant. Statistically, therefore, the effectiveness of the soil treatments is established with a very high degree of probability, and thus the experiment confirms the finding of the Methods experiments previously detailed. Table 7 summarizes the complete results of the experiment.

TABLE 7.—RELATIVE EFFECT ON THE AMOUNT OF DISEASE AND ON THE YIELD OF MINDUM WHEAT OF DIFFERENT METHODS OF INSURING POSITIVE ATTACKS OF ROOT/ROT OF WHEAT CAUSED BY *Fusarium culmorum*

Disease Rating

Method of introducing *F. culmorum* into the soil	Seed Treatments				Mean*	Standard error of means of soil treatments
	Ceresan	DuBay	Copper carbonate	Control		
Seed inoculation plus soil inoculum	70.9	68.8	74.5	75.2	72.3	
Seed inoculation	65.8	64.3	71.0	76.3	69.3	0.90
Control	59.2	65.4	58.9	57.6	60.3	
Yield (Bushels per acre)						
Seed inoculation plus soil inoculum	15.6	17.5	14.7	14.8	15.6	
Seed inoculation	19.2	18.6	18.6	14.8	17.8	0.69
Control	20.8	15.9	21.5	21.5	19.9	

*To be significant the differences between means of soil treatments must exceed 2 $\sqrt{2}$ x Standard error.

Examination of Table 7 shows that the amount of root rot was markedly increased in 1933 by applying inoculum of *F. culmorum* to the seed and soil. Seed inoculation was effective when used separately, and with soil inoculum. The mean yield difference observed between plots which were planted with inoculated seed and the controls just reached significance, while the employment of both seed inoculation and soil inoculum methods to introduce *F. culmorum* into the soil resulted in a mean difference in yield between plots so treated and the controls which was statistically significant.

DISCUSSION

Henry *(9)*, and Sanford and Broadfoot *(15)* have demonstrated that the natural microflora of soil has a marked inhibitive effect on the development of cereal root-rotting fungi. Their results seem to offer a partial explanation of the frequent failures to obtain successful root infections on cereal plants where inoculum of *Helminthosporium sativum* and *Fusarium culmorum* has been applied to the soil. It would seem that, owing to the

marked influence of the natural soil flora on plant pathogens, soil, infested naturally with *H. sativum* and *F. culmorum*, would be most suitable for field experiments. Inasmuch as it is difficult to secure naturally-infested fields for experimental purposes, it is necessary to develop an effective and practical field technique for inducing positive attacks with *H. sativum* and *F. culmorum*.

Experiments here reported were made with ordinary field soil. Consequently, due to the natural fungous flora, a considerable amount of infection occurred on the roots and basal parts of cereal plants even when inoculum of a parasitic fungus had not been applied to the seed or to the soil. Tables 4 and 5 show that the degree of infection on the underground parts of plants grown in ordinary field soil (controls) was relatively severe in 1931, 1932 and 1933. These results emphasize the importance of planning root rot field experiments so that differences in disease infection and yield arising from various seed and soil treatments can be properly evaluated.

To provide a fair test of the relative effectiveness of several competing treatments for controlling soil-inhabiting fungi, such as the root rot pathogens, field plots sould be so arranged that the heterogeneity of the soil as well as differences between the treatments themselves can be accurately determined. The Randomized Block plan of plot arrangement, as used in these studies, makes a very desirable arrangement for root rot experiments. This method permits an adequate evaluation of heterogeneity arising from sources other than the treatments themselves. Furthermore, the application of statistical methods to the interpretation of field experiments is essential in order to obtain a more accurate appreciation of the experimental errors involved, and of the significance attached to any result.

The field methods described in this paper should lead to practical applications of importance in testing seed and soil treatments for the control of root rot diseases of cereals, and in studying the comparative resistance and susceptibility of cereal varieties to root rots caused by species of *Helminthosporium* and *Fusarium*.

SUMMARY

For the last three years, carefully planned field experiments have been made to determine efficient and practical methods of artificially creating destructive attacks of root rot diseases caused by *Fusarium culmorum* (W. G. Sm.) Sacc. and *Helminthosporium sativum* P., K., and B. on cereals. Especial attention was given to the arrangement of the experiments, methods of planting, soil infestation, harvesting, and recording and analyzing root/rot experimental data.

The extent of disease was expressed as a disease rating, which represents the percentage of the total number of plants which were infected and also the degree of infection. Each year, during the course of the investigation, the disease rating in a series of plots of Marquis wheat was varied by employing various devices to introduce root-rotting fungi into the soil. In the final analysis of the results of each experiment the disease ratings of individual plots were correlated with the yields. The results are summarized in the form of correlation coefficients.

The values of the coefficients obtained were highly significant, and hence it was concluded that the disease rating is an accurate measure of the amount of root rot caused by *F. culmorum* and *H. sativum* on cereals. It was demonstrated that *Fusarium* and *Helminthosporium* root rot diseases have a marked detrimental effect on the yield of wheat.

Various methods have been employed to induce severe attacks of root rot in the field. Of those tested, the seed spore-suspension method of introducing the fungus into the soil was most satisfactory with *F. culmorum*. Significant increases in disease rating and significant reductions in yield were obtained wherever this method was employed. The method has distinct practical advantages for field work.

A combination of two methods, namely, the inoculation of seed with a suspension of conidia and the application of oat-hull inoculum to the soil, gave the most satisfactory results with *H. sativum*. All the methods studied so far have failed to give a real epidemic of *Helminthosporium* root rot.

The results have emphasized the value and importance of plot arrangement, and the application of statistical methods to the interpretation of the results of field experiments with rootrot diseases of cereals.

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Résumé

Etudes sur le traitement des pourritures du pied des céréales causées par *Fusarium Culmorum* (W.G.Sm.) Sacc. et *Helminthosporium Sativum*, P. K. et B. I. Méthodes suivies en plein champ. F. J. Greaney et J. E. Machacek, Laboratoire fédéral des recherches sur la rouille, Winnipeg, Man.

En ces trois dernières années on a cherché, par des expériences dont le plan avait été soigneusement tracé, des moyens pratiques et efficaces de créer des attaques destructives des pourritures des racines, causées sur les céréales par *Fusarium culmorum* (Wm. G. Sm.) Sacc. et *Helminthosporium sativum* P. K., et B. Ceux qui étaient chargés de la conduite de ces expériences ont donné une attention toute spéciale à leur préparation, au mode de plantation, à l'infection du sol, à la récolte, ainsi qu'à l'enregistrement et à l'analyse des données expérimentales. La fréquence de la maladie a été exprimée sous forme d'indice, représentant le pourcentage du nombre total de plantes affectées ainsi que le degré d'infection. Chaque année, au cours de cette enquête, on a varié l'indice de la maladie dans une série de parcelles de blé Marquis en employant différents moyens pour introduire dans le sol les cryptogames qui causent la pourriture. Dans l'analyse finale des résultats de chaque expérience, les indices de maladie des parcelles séparées ont été reliés aux rendements. Les résultats sont résumés sous forme de coefficients de corrélation. Les valeurs des coefficients obtenus ont été très significatives et c'est pourquoi on a conclu que l'indice de la maladie est une mesure exacte de la quantité de pourriture causée par *F. culmorum* et *H. sativum* sur les céréales. Il a été démontré que les maladies *Fusarium* et *Helminthosporium* exercent un effet très nuisible sur le rendement du blé. Différents moyens ont été employés pour provoquer de graves attaques de la pourriture dans le champ. De tous ces moyens, celui qui s'est montré le plus satisfaisant pour le *F. culmorum* est le procédé qui consiste à introduire le cryptogame dans la terre au moyen d'une suspension de spores. Chaque fois qu'on a eu recours à ce moyen, on a obtenu un relèvement significatif de l'indice de la maladie et une réduction sensible de rendement. Ce procédé présente des avantages pratiques distincts pour les travaux en plein champ. Une combinaison de deux méthodes, savoir, l'inoculation de la semence avec une suspension de conidies et l'application d'inoculum de balle d'avoine au sol, a donné les résultats les plus satisfaisants en ce qui concerne *H. sativum.* Tous les moyens employés jusqu'ici n'ont pas réussi à provoquer une réelle épidémie de la pourriture *Helminthosporium.* Ces résultats ont fait ressortir l'utilité et l'importance de l'arrangement en parcelles et de l'application de la statistique à l'interprétation des résultats des expériences en plein air sur la pourriture du pied des céréales.

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THE ECONOMIC SITUATION

PREPARED IN THE AGRICULTURAL ECONOMICS BRANCH, DEPARTMENT OF AGRICULTURE, OTTAWA, FROM BASIC DATA COLLECTED BY THE DOMINION BUREAU OF STATISTICS

The index number of wholesale prices in Canada receded from 72.0 in September to 71.4 in October. The index of vegetable products declined nearly 2 points while lesser recessions were registered in the indexes of fibres, textiles and textile products; wood, wood products and paper; chemicals and allied products. Gains were reported for animal products; iron and its products; non-ferrous metals, and non-metallic minerals. On the whole wholesale prices have been consistently above the level of 1933.

Retail Prices.—The index of retail prices, rents and costs of services advanced from 79.0 in September to 79.3 in October. The sub-index of food rose from 68.8 to 69.4. The fuel index advanced from 88.0 to 88.5 and that of rentals from 79.7 to 80.3. The latter index is of interest because it has been declining steadily since May, 1930. During the first nine months of 1934 the monthly index number of the value of retail sales has been below that of corresponding months in 1933 only in April and September.

Physical Volume of Business.—The index of the physical volume of business declined from 97.1 in September to 95.8 in October. Industrial production fell from 97.5 to 95.3. Mineral production rose from 132.7 to 141.9 chiefly on account of substantial gains in exports of zinc and copper and in shipments of gold. Output of silver, asbestos, nickel and lead was slightly lower, while coal production was barely maintained. The index of manufacturing fell from 99.5 in September to 94.6 in October. Flour production was lower but sugar production and tobacco releases were larger. Imports of crude petroleum, textiles and rubber were lower compared with the previous months. The forestry products' index advanced from 93.8 to 100.3 chiefly on account of the rise in production of newsprint. Exports of wood pulp, and shingles were higher but fewer planks and boards were shipped abroad. The index of iron and steel products was lower in October. The construction index was lower than in September although the number of building permits was greater. Production of electric power gained. Agricultural marketings were lower but storage holdings were higher than in September.

Agricultural Products.—Prices of agricultural products were on the whole lower than in September. The index, therefore, declined to 60.9. The index of prices of field products fell from 58.9 to 55.3,, lower prices for grains and potatoes being largely responsible. The average price of No. 1 Manitoba Northern Wheat was 82.3 cents per bushel, basis Fort William and Port Arthur, in September, whereas in October the average price was 78.2 cents per bushel. Similarly prices of No. 2 C. W. oats fell from 45.7 to 41.5. No. 3 C. W. barley declined from 58.5 cents to 51.6 cents per bushel. Grain marketings were lower than in September. The index

ANNUAL AND MONTHLY INDEX NUMBERS OF PRICES AND PRODUCTION COMPUTED BY DOMINION BUREAU OF STATISTICS

Year	Wholesale Prices 1926 = 100				Retail prices and cost of services (5)	Production (6) 1926 = 100			
	All commodities (1)	Farm products (2)	Field products (3)	Animal products (4)		Physical volume of business	Industrial production	Agricultural marketings	Cold Storage holdings
1913	64.0	62.6	56.4	77.0	65.4				
1914	65.5	69.2	64.9	79.0	66.0				
1915	70.4	77.7	76.9	79.2	67.3				
1916	84.3	89.7	88.4	92.3	72.5				
1917	114.3	130.0	134.3	119.6	85.6				
1918	127.4	132.9	132.0	134.7	97.4				
1919	134.0	145.5	142.4	152.5	107.2	71.3	65.5	48.1	47.1
1920	155.9	161.6	166.5	149.9	124.2	75.0	69.9	52.6	94.2
1921	110.0	102.8	100.3	108.5	109.2	66.5	60.4	65.2	86.4
1922	97.3	86.7	81.3	99.1	100.0	79.1	76.9	82.6	82.8
1923	98.0	79.8	73.3	95.1	100.0	85.5	83.8	91.4	87.6
1924	99.4	87.0	82.6	97.2	98.0	84.6	82.4	102.5	114.9
1925	102.6	100.4	98.1	105.7	99.3	90.9	89.7	97.2	108.6
1926	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1927	97.7	102.1	99.9	105.7	98.4	106.1	105.6	103.6	110.0
1928	96.4	100.7	92.6	114.3	98.9	117.3	117.8	146.7	112.8
1929	95.6	100.8	93.8	112.5	99.9	125.5	127.4	101.1	109.6
1930	86.6	82.3	70.0	102.9	99.2	109.5	108.0	103.0	128.4
1931	72.2	56.3	43.6	77.6	89.6	93.5	90.4	99.0	125.7
1932	66.7	48.4	41.1	60.7	81.4	78.7	74.0	114.3	120.1
1933	67.1	51.0	45.8	59.6	77.7	79.7	76.8	105.1	115.4
1933									
Jan.	63.9	43.6	35.1	57.9	79.1	68.1	62.2	56.1	112.0
Feb.	63.6	43.0	36.0	54.7	78.4	67.0	60.0	76.5	127.6
Mar.	64.4	44.7	38.0	56.0	77.8	68.4	62.5	129.0	135.8
April	65.4	46.8	41.1	56.4	78.0	69.8	65.1	104.1	112.7
May	66.9	51.2	46.9	58.4	77.0	76.4	72.7	95.4	110.4
June	67.6	52.6	49.4	57.9	77.0	82.2	79.8	221.9	119.9
July	70.5	60.1	60.8	59.0	77.2	84.1	82.6	221.9	119.9
Aug.	69.4	57.0	54.9	60.5	78.6	89.8	89.5	197.2	114.2
Sept.	68.9	54.7	49.5	63.4	78.5	90.8	90.2	101.1	115.7
Oct.	67.9	51.4	44.6	62.8	77.9	88.2	87.4	70.5	112.7
Nov.	68.7	53.8	46.7	65.8	78.1	85.5	83.9	41.8	111.1
Dec.	69.0	53.3	45.3	66.6	78.4	86.2	85.1	30.7	107.6
1934									
Jan.	70.6	55.3	47.9	67.8	78.2	86.8	84.5	48.2	108.1
Feb.	72.1	58.0	49.3	72.5	78.7	86.4	84.0	67.1	98.6
Mar.	72.0	56.5	49.5	68.3	79.9	93.1	92.0	63.8	97.0
Apr.	71.1	55.4	48.7	66.6	79.4	92.6	91.4	56.9	94.5
May	71.1	56.9	51.1	66.5	78.5	99.6	99.4	130.6	102.6
June	72.1	59.3	55.5	65.6	78.2	95.8	95.2	97.2	126.1
July	72.0	60.0	57.8	63.7	78.4	95.7	95.6	148.8	116.3
Aug.	72.3	61.6	60.7	63.1	78.7	99.0	99.8	172.8	114.7
Sept.	72.0	61.3	58.9	65.3	79.0	97.1	97.5	127.7	117.7
Oct.	71.4	60.9	55.3	70.4	79.3	95.8	95.3	61.2	128.3

1. See Prices and Price Indexes 1913-1928, pp. 19-21, 270-289 and 1913-1931, p. 15.

2. Wholesale prices of Canadian products of farm origin only. See Prices and Price Indexes 1913-1931, p. 33, and Monthly Mimeographs 1933 and 1934.

3. Wholesale prices of grains, fruits and vegetables.

4. Wholesale prices of Animals and Animal Products.

5. Including foods, rents, fuel, clothing and sundries, See Prices and Price Indexes 1913-1928, pp. 181-185, 290-293. 1926=100.

Prices and Price Indexes 1913-1931, p. 122, and Monthly Mimeographs 1933-1934.

6. Monthly Review of Business Statistics, p. 8, and Monthly Indexes of the Physical volume of business in Canada, supplement to the Monthly Review of Business Statistics, November, 1932.

dropped from 139.0 to 57.9. The decline in receipts of wheat, barley and oats at the head of the lakes was particularly noticeable.

In the case of animal products the index rose from 65.3 to 70.4. This advance was due to higher prices for milk, eggs, hides, and skins which more than offset lower prices for cattle, hogs, and wool.

Marketings of live stock were very little below those in September, the index receding from 76.7 to 75.7. Cattle, calves and sheep were marketed in larger numbers but receipts of hogs were below those in the previous month.

Cold storage holdings advanced from 117.7 in September to 128.3 at the first of October. Supplies of eggs, butter, beef, pork and lard, cheese, mutton, veal and poultry increased.

The Outlook for 1935.*—Business conditions in Canada continued to improve in 1934. Physical volume of business was higher than in 1933 and wholesale prices advanced. Prices of farm products also showed some improvement and as a result the farmers' position is somewhat better than a year ago. Present indications lead to the belief that there will be further gradual improvement in 1935.

Foreign demand will continue to be affected by trade barrier tendencies. There are, however, indications of rising prices and increased purchasing power. The employment situation in Great Britain has improved although there has been a tendency during recent months for living costs to rise.

Wheat has been moving more rapidly from farms during the present crop year than was the case a year ago but prices are still low and demand has not risen as rapidly as was anticipated. A careful analysis of the wheat situation suggests that Canadian wheat growers would be well advised to refrain from expanding wheat acreage in 1935. There seems to be opportunity for increasing acreages of oats, barley, rye, buckwheat, flax, and corn since reserves of these commodities are comparatively low and feed requirements may be high.

In regard to live stock, prospects are that total supplies of commercial cattle will be larger than in 1934. Some improvement in prices for good to choice cattle in the early winter is anticipated. The export market in Great Britain is not expected to show any appreciable change, although the shortage in the United States may react favourably upon the cattle industry in Canada. There are prospects for a moderate increase in exports of bacon to the United Kingdom in 1935 and hog marketings will not vary greatly from those of 1934. The domestic market for hogs should be slightly better if the anticipated improvement in prices of beef cattle takes place.

The production of sheep in Western Canada has grown to some extent but in Eastern Canada there has been a decline. The demand for lambs has been very brisk and therefore resulted in improvement in the sheep raising industry. Prospective supplies for 1935 would appear to be adequate. The wool market opened very briskly but has declined to some extent in recent months. On the whole, however, it has been fairly satisfactory.

The outlook for both poultry and eggs is reported to be more favourable than in 1934 when improvement over the previous year was shown.

Milk production continued an upward trend, larger quantities being diverted to the fluid milk market and to the manufacture of creamery butter. An outstanding feature of 1934 was the continued decline in the production of cheese. Indications are that unless there is a sharp rise in the price level, income from dairy products is not likely to increase to any great extent in 1935.

Improvement in demand for fruits and vegetable would indicate that markets for these products will at least be maintained at, or slightly above, the 1934 level. The extent of injury to apple trees during the winter of 1933-34 amounting to 40-50 per cent in Ontario will continue to affect supplies. Production of other tree fruits will probably be maintained. Prospects are that there will be an increase in the proportion of small fruits and vegetables produced for processing.

*Based upon preliminary reports of committees engaged in preparing the Agricultural Situation. 1935.

THE COMBINE HARVESTER

E. G. Grest[1]

During the summer of 1931 the Economics Branch co-operating with the Canadian Pioneer Problems Committee, the University of Saskatchewan and the University of Alberta, made an extensive study of Farm Power in Saskatchewan and Alberta. The analysis of data relating to combine harvester costs is briefly reported in this article. The areas in which the data were obtained are Davidson, Craik, Maple Creek and Richmond in Saskatchewan and Irwine, Hilda, Foremost, Bow Island and Olds, Alberta.

The areas visited in the southern parts of the two Provinces were fairly well suited to the use of combines for harvesting the wheat crop. A total of 63 combines was found on the farms included in the survey, 56 of which were found on farms in the southern areas and 7 on the farms near Davidson, Saskatchewan. Comparison of the combine harvester with the binder or header and threshing methods of harvesting crops is not attempted. More complete information than that included in this study would be necessary for a proper comparison of these methods. In areas where climate, uniformity of soil and regularity of topography make conditions favourable for combining this method of harvesting will probably be popular and profitable but where the crop ripens late in the fall and ripens unevenly or where the weather is likely to be damp or wet during the harvesting season, the risks encountered in the use of the combine harvester are serious. The losses in some years will be so large that harvesting by this method will prove more costly than when binders or headers and threshing machines are used.

Costs of Operation and of Harvesting per Acre.—The costs of operating the combines for which data were obtained and the cost of harvesting a crop per acre, not including the hauling of grain, are shown in Table 1. The cash costs to operate the combines, including labour and power to pull them, were $144.80 for 15 and 16 foot machines and $120.50 for 10 and 12 foot machines for the year 1930. Despite having a larger cutting bar the 15-16 foot combine was operating at 20 cents per acre while for the 10-12 foot combine the cost was 16 cents per acre. The lower cost per acre for the smaller machines was due to a greater number of acres harvested, an average of 736 acres in comparison to 709 for the larger combines. Interest, depreciation and servicing charges were also higher for the larger machines and thus, total operating expenses per acre for the 15-16 foot size were 92 cents while that of the 10-12 foot size were 80 cents per acre. If the larger machines had harvested as much crop in proportion to their size as the smaller ones then the operating expenses of each would have been more nearly the same.

The cost of man labour per acre required to operate the combine and tractor and the cost of tractor power to pull the combine was found to be slightly higher for the smaller machines. More acres were harvested per hour with the larger units thus lowering the cost of man labour per acre. The cost of tractor power was also lower in the case of the larger combine because, in many cases, the same size of tractor was used to pull both sizes of machines. A two-plow tractor can pull a 10-12 foot combine satisfactorily on level ground but the three-plow tractor is more generally used. A 15-16 foot combine is often drawn by a three-plow tractor and nearly as often by a four-plow size. Therefore, when calculating the cost of tractor power to haul the combines the average rate for the three-plow tractors was used for the 10-12 foot combines and a rate equivalent to using a three-plow tractor half time and a four-plow tractor the balance of the time was used for the 15-16 foot machines.

The total costs of harvesting a crop in 1930 were $1,138.80 per combine for 15-16 foot machines and $1,164.30 per combine for 10-12 foot machines. Reduced to an acreage basis the cost for the larger machine was $1.61 per crop acre compared to

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Table 1.—Combine operating costs and cost of combining per acre, Davidson, Sask. and Southwestern Sask. and Southeastern Alberta, 1930 crop

	Size of Combine			
	15′ to 16′		10′ to 12′	
Number of combines	48		15	
Average acres harvested 1930	709		736	
Average value $	1,736		1,624	
Average size of farm (acres of cropland)	729		669	
	Per combine	Per acre harvested	Per combine	Per acre harvested
	$	$		$
Gallons of fuel used		0.41		0.46
Cost of fuel		0.11		0.12
Gallons of cylinder oil		0.02		0.02
Cost of cylinder oil		0.03		0.02
Cost of grease		0.01		0.01
Cost of hired labour repairing		0.01		
Cost of parts		0.04		0.01
Total cash costs	144.8	0.20	120.5	0.16
Interest at 6 per cent	104.1	0.15	97.5	0.13
Depreciation	371.4	0.53	356.3	0.48
Hours servicing, overhauling	57.4	0.08	46.8	0.06
Value of servicing[1]	31.6	0.04	21.9	0.03
Total operating costs	651.9	0.92	596.2	0.80
Cost of two men to operate combine and tractor[1]	204.0	0.29	247.7	0.34
Cost of tractor power to pull combine[2]	282.9	0.40	320.4	0.44
Total cost to combine crop	1,138.8	1.61	1,164.3	1.58

$1.58 per acre for the smaller 10-12 foot combine. As stated before, the higher cost per acre for the 15-16 foot combines was due mostly to a smaller acreage handled per machine. If the large combines had been handling the same number of acres per foot of cutting bar as compared to the smaller ones then the cost of harvesting would probably have been 10-12 cents higher per acre for the small machines than that of the larger units.

Relation of Acres Harvested to Cost.—The combine harvester is a relatively expensive machine and, therefore, when a farmer purchases one he must have as many acres per year as possible in order to reduce the overhead costs of interest and depreciation due to obsolescence to a reasonable figure per acre. In most cases 700 acres or more for a 15-16 foot combine and 525 acres or more for a 10-12 foot combine must be harvested per year to obtain a reasonable cost per acre of crop harvested. When conditions are not particularly favourable for combining it might be necessary to plan on harvesting fewer acres per season to reduce the risk of loss to the standing crop due to early snow-storms even though the cost of harvesting per acre is increased. The data were sorted according to the acres harvested in 1930 and the resulting operating costs per acre and the total cost of harvesting per acre were obtained. These data are presented in Table 2.

It will be noticed that in both cases the difference in cost between the group having the lowest number of acres harvested and the middle group is very great but the difference between the middle group and the groups having the highest acreage harvested is small amounting to 12 cents per acre for the 15-16 foot combines and 23

[1]The man-labour rate for servicing these combines was 53.35 cents per hour. This rate was used to calculate the cost of the operator's labour of the combine and the tractor.

[2]The tractor rate used for 16′ combines was $1.48 and $1.38 for the 12′ combines.

TABLE 2.—ACRES HARVESTED PER YEAR, TOTAL COST OF OPERATING COMBINES PER ACRE, AND TOTAL COST OF COMBINING A CROP PER YEAR

	Acres harvested					
	15′-16′ combines			10′-12′ combines		
	100-499	500-899	900-1340	75-374	375-674	675-1130
Number of combines	10	25	13	2	6	7
Acres harvested per combine	296	687	1,070	295	536	1,033
Acres cropland per farm	563	751	814	378	662	758
	$	$	$	$	$	$
Total cost of operating combine per acre	1.58	0.91	0.79	1.38	0.94	0.71
Cost per acre:						
2 men operating	0.29	0.29	0.29	0.34	0.34	0.34
Tractor power	0.40	0.40	0.40	0.44	0.44	0.44
Total cost of harvesting per acre of cropland	2.27	1.60	1.48	2.16	1.72	1.49

cents for the 10-12 foot combines. Therefore, up to 700 acres or somewhat over, the saving in increased acres harvested per combine is large for the 15-16 foot combines. The same condition holds true up to 525 acres for the 10-12 foot combines. In the higher acreage groups although the saving with increased acres harvested is still quite evident it is not nearly so marked and, in some areas, it may not be profitable to plan on harvesting more acres due to the increased risk of crop loss.

THE AGRICULTURAL SITUATION

Through the co-operation of the Department of Trade and Commerce and the Department of Agriculture, the second annual review of the Agricultural Situation will appear early in January. The purpose of this review is to bring into concise form all the known factors affecting the supply of and demand for agricultural products in both domestic and foreign markets. With this information as a basis, farmers may adapt production and marketing policies to changing economic conditions; extension workers will be provided with data upon which to plan their programs; administrative officers will be assisted in formulating policies regarding production and marketing; and those responsible for the advancement of information to farmers will be able to present a more unified point of view with respect to the immediate future and the longer trends in agricultural production.

The report will include an analysis of foreign demand and competition; the domestic situation and each of the more important farm products will be considered separately. In this way, a rather comprehensive survey of the whole situation is anticipated. It is believed that this service will become increasingly important in the work of both Federal and Provincial Departments of Agriculture. The Provincial Departments of Agriculture in Saskatchewan and Nova Scotia have during the past two years prepared Outlook reports for distribution to farmers in their respective provinces and it is hoped that such policies may be possible in other provinces as well so that the farmer will be supplied with the best available economic information upon which to plan his business operations for 1935.

The report has been prepared by committees composed of officers from the Department of Trade and Commerce and the Department of Agriculture who will meet with representatives of the Provincial Departments of Agriculture and Agricultural Colleges in a three day session to be held in Ottawa, November 29th, 30th and December 1st at which the final draft will be completed. This bulletin will be distributed by the Publications Branch of the Department of Agriculture, Ottawa.

OBSERVATIONS ON THE ECONOMIC PROBLEMS OF GROWING FRESH VEGETABLES IN THE SOUTHERN INTERIOR OF BRITISH COLUMBIA[1]

A. E. RICHARDS[2]

Relatively high cost of production and the perishable nature of the product make vegetable growing one of the most hazardous of farming ventures. This is a general statement, but one which seems quite applicable to vegetable growing on the irrigated lands of the Southern Interior of British Columbia. In that area it has become a specialized type of farming and profitable returns have proven highly speculative. Markets for the crop have been transitory. Early commercial shipments which date back to the nineties and preceded fruit shipping on a commercial scale supplied mining camps in the Kootenay Valley and other mining districts in the province. The rapid populating of the prairies followed and the industry expanded to supply that market.

Following the war many of the mines were closed and that market restricted and now some observers hold the view that the British Columbia grower is gradually losing his command of the prairie market. There was a time when vegetable growing on the western prairies of Canada was not seriously considered as a commercial enterprise. By selection and improvement, varieties adaptable to the prairie growing season are now being produced in quantity and it is claimed by interested authorities that the three prairie provinces are rapidly moving towards a self sustaining position in respect to certain vegetables. Movement is reported of a number of growers of vegetables from the higher priced lands of the Okanagan Valley in British Columbia to irrigated prairie lands in the neighborhood of cities and towns in Southern Alberta. The statement is also made that British Columbia vegetable growers must look more and more to an off-season market on the prairie. While the local supply is in season it commands the market and the preference. It is placed on the prairie city markets in a fresher condition and without the handicap of a long transportation haul. There is another supply factor which may be taken into consideration. Due to the low price of grain it has been stated that a number of prairie farmers have turned their attention to vegetable production as a side line and undoubtedly they are growing more vegetables to-day for home use than in former years.

On the other hand the growing of vegetables on the prairies is precarious due to weather conditions. The Southern Interior of British Columbia has a more reliable and a longer growing season which enables the product of that area to be placed on the market before and after local supplies are available. Storage facilities in the Okanagan Valley also enable the vegetable growers to extend the marketing period considerably beyond the usual growing season.

A study of importation statistics shows that the United States still provides a large proportion of the prairie cities' vegetable supplies, a great deal of it being sold in direct competition with British Columbia products at a time when they are in season. The British Columbia growers are displacing the imported products no doubt to a certain extent, as production figures show that supplies and movement of tonnage to the prairie have been maintained over the past few years. While there has been a dropping off in the movement from British Columbia of some kinds of prairie grown vegetables, there has been an increase in certain other vegetables not commonly grown on the prairie lands. These include asparagus, peppers, eggplant, citron and cantaloupes.

The total vegetable acreage in the Interior of British Columbia has averaged 9,146 acres in the last ten years. During that period 1926 was the peak year with 10,303 acres. For 1934, an area of 8,194 acres was reported. The average annual

[1] This article is based on interviews and observations during the writer's visit to the Okanagan Valley and is presented as the popular view rather than a subject of research.

[2] Agricultural Economist, Economics Branch, Department of Agriculture, Ottawa.

value for four years 1927-1930 of the vegetable crop in the Interior of British Columbia was estimated at $1,501,980. Of this the cannery vegetable crops accounted for about one-fifth.

Table 1 shows the production of seven vegetables including tomatoes and cantaloupes during the last five years in the Interior of British Columbia.

Table 1.—Production of Vegetables in the Southern Interior of British Columbia 1929-33*

Year	Semi-ripe tomatoes	Cannery tomatoes	Lettuce	Cucumbers	Celery	Onions	Cantaloupes	Potatoes
	crates	tons	pkgs.	pkgs.	tons	tons	crates	tons
1929	292,285	18,994	28,599	175,079	1,044	10,938	10,000	6,983
1930	264,894	25,582	12,908	138,697	826	8,720	13,050	6,170
1931	347,530	8,371	19,378	175,271	959	10,681	11,537	7,486
1932	294,860	8,939	20,587	96,947	782	13,089	20,756	4,958
1933	371,672	13,435	13,406	122,779	1,047	10,184	30,239	8,460

*Statistics from British Columbia Department of Agriculture, Vernon, B.C.

Out of the 8,194 acres estimated to be planted to vegetables in the 1934 season, 6,541 acres or 80% include those named in the Table 1. This table indicates that production although variable has not dropped to any appreciable extent during the last five years. Available statistics showing car arrivals at various prairie points do not differentiate between Interior of British Columbia and the Lower Mainland shipments. The whole of British Columbia is included in the one classification and it shows that shipments from the province have not been reduced as would be expected with growing competition from prairie vegetables. That British Columbia vegetables are displacing importations seems a reasonable conclusion which is further exemplified in Table 2.

Table 2.—Arrivals of Car Loads of Vegetables at Cities in Western Canada from British Columbia and United States 1931-33*

	Calgary		Edmonton		Regina		Winnipeg	
	B.C.	Imported	B.C.	Imported	B.C.	Imported	B.C.	Imported
	cars	cars	cars	cars	cars	cars	cars	cars
1931	473	221	374	172	182	167	145	603
1932	361	165	305	113	184	113	160	422
1933	501	136	352	84	122	93	215	352

*Statistics from Dominion Fruit Branch, Ottawa; cars of mixed fruit and vegetables included in items.

Average prices for the past eight years for a number of kinds of vegetables are given in Table 3. They show considerable variation from year to year with the usual decline from the peak years of 1928 and 1929. Prices improved somewhat in 1933 and this season to date are considered to be as good as last year.

In addition to competition for markets the original growers who are mainly of British origin from Eastern Canada and the British Isles are faced with competition in the production of their vegetable crops. This is largely a racial problem. A very large number of the growers at the present time and an increasing proportion are of other nationalities. With all members of the family in the field, working from daylight to dark, seven days a week, and with their different standard of living it is claimed that

TABLE 3.—AVERAGE F.O.B. PRICES FOR A NUMBER OF VEGETABLES AT INTERIOR OF BRITISH COLUMBIA SHIPPING POINTS, 1926-33*

—	Onions	Semi-ripe tomatoes	Cannery tomatoes	Cucumbers	Lettuce	Cantaloupes	Celery
	per ton $	per pkge. $	per ton $	per pkge. $	per crate $	per crate $	per lb. $
1926	20.00	1.00	16.50	0.45	2.40	1.75	0.02
1927	35.00	1.00	—	0.54	2.50	2.27	0.02¼
1928	40.00	0.65	—	0.65	1.80	2.50	0.02¼
1929	32.00	1.30	17.50	0.70	3.00	2.20	0.03½
1930	30.00	1.05	17.50	0.60	2.30	2.10	0.03½
1931	20.00	0.60	—	0.40	1.80	1.65	0.03
1932	12.00	0.50	10.00	0.35	1.50	1.75	0.03
1933	15.00	0.60	10.00	0.35	1.25	1.75	0.03

*Statistics from British Columbia Department of Agriculture, Vernon, B.C.

they have displaced the original grower or forced him for economic reasons to rent his land. Although a number of the original settlers are endeavouring to hold their homes and holdings established in the growing of vegetables they cannot adjust themselves to the competitive standards and habits of living. The situation becomes a sociological problem of grave importance to the permanent welfare of the Valley.

Basis of sale.—Most of the vegetable crop is sold for cash with payment within two weeks from time of delivery. As a general rule the foreigner does not understand the complexities of the market. He does not comprehend pooling and waiting for returns and is willing to accept less for cash. Straight purchase has, therefore, become the general practice among independent as well as co-operative shipping houses. As there are usually more marketable vegetables offered than can be marketed, price cutting and consigning come into play, all of which bring about market instability. The perishable nature of the product aggravates the problem and it is frequently rushed on to an already over-stocked market. This results in a further break in price and often loss to the grower. Some growers complain of the activities of certain shippers who, on an expected rising market, act as dealers and buy at a firm price with a chance for profit. When the market tends to swing downward they become agents operating on a commission basis and leave chance for loss to the grower.

A considerable proportion of the vegetable crop is moved to market centres in mixed carloads containing fruit and some vegetables. The complaint is frequently heard among growers that their vegetables are used as "loss leaders" to make contacts with the trade at receiving centres and to help sell the fruit.

System of Land Tenure.—The original growers are land owners. Only a small proportion of the foreign population own land in the interior of British Columbia although the number is increasing. In the Ashcroft, Kamloops and Vernon areas vegetable growing is largely on a cash rental basis. In the Kelowna district about 70% is on a share basis and 30% cash rented. Under this crop-share plan the owner provides land and water, pays all taxes, does all horse work, supplies one-half the seed or plants and sacks together with 50% of fertilizer and cut worm poison. The land owner supplies the tenant with a house to live in. In hauling manure the tenant supplies help. The tenant plants, cultivates and harvests the crop. The crop itself or the proceeds of the crop are shared by owner and tenant on a fifty-fifty basis.

In the cash rental districts the tenants are largely of Chinese origin. The landlord receives a rental of $10 to $15 per acre and in certain districts the renter pays an additional charge of $5 or $6 per acre for water to irrigate his land. In the Ashcroft district the ranchers are few in number but their land holdings are large. They are

nearly all cattlemen, with irrigated hay land on the flats under private irrigation systems. The renter fits into the ranch organization. He irrigates the hay land and grows vegetables as a cleaning crop in a crop rotation on the older stands of alfalfa.

Size of Holdings and Hired Labour.—The size of holdings of specialized vegetable growers vary with an average of about ten acres per holding. Several vegetables are usually grown in combination with one or two kinds as major crops. Four acres form a one man unit of onion production for the tenant with additional help at thinning and harvesting. Eight acres is regarded as a one man unit for tomatoes on the rented lands. On a ten acre block of tomatoes a man and his wife work all through the season with one helper. During planting and harvesting additional help is hired. On a ten acre block of onions a man and his wife do practically all the work themselves. Such industry means long hours of work every day in the week without relaxation or social recreation.

INTERNATIONAL CONFERENCE OF AGRICULTURAL ECONOMISTS

Three Canadians—Dr. J. E. Lattimer, Macdonald College, P.Q., Dr. W. Allen, University of Saskatchewan and Dr. T. W. Grindley, Dominion Bureau of Statistics—attended the Third International Conference of Agricultural Economists at Bad Eilsen, Germany from August 26 to September 1. The meetings were held at a quiet resort situated in the Weser valley of Lower Saxony. While the immediate vicinity of Bad Eilsen is pleasantly hilly and wooded, the surrounding country forms one of the finest farming regions of Germany. Well-directed trips through the farms gave the delegates an opportunity to become acquainted with the methods of husbandry. The intensive cropping and the strip-farming which has continued since the Middle Ages were the most interesting features to overseas visitors.

The objective of the Conference was to provide an opportunity for discussing fully and frankly the many problems that have arisen out of the world agricultural crisis, the various means taken to meet them and the possible ways for definitely overcoming them through national action and international co-operation. In the formal discussions but particularly outside the conference room, the problems of agriculture were thoroughly covered. The means of correction were found by the speakers to lie almost entirely within the field of national action and the methods of correction differed so greatly among the countries that the benefits of discussion were somewhat diminished. "International co-operation" in the discussions was practically limited to the opening remarks of the President, who sponsored the gospel of more trade and more credit, based on more faith between nations. The discussion, however, quickly turned to practicality and nationalism. Striving for independence—agricultural, commercial and financial—most countries of the world have gone far into the field of uneconomic production. Control policies are being formulated everywhere to build up the nations within their borders and with consequent depreciating influences on world trade. This, plainly enough, is a situation which Canada must appreciate; our hope for the present and at least for the immediate future lies in Empire trade and, to a lesser extent, in trade with the United States and South America.

The Conference proper was presided over by the President, Mr. L. K. Elmhirst, ably supported by the Vice-presidents, Dr. Sering, Deutches Forschungsinstitut Für Agrar und Siedlungswesin, Berlin and Dr. Warren of Cornell University, Ithaca, N.Y. Dr. Zorner of Berlin and J. P. Maxton of Oxford also did a great deal to make the Conference a success. The language difficulty was well handled through concurrent translation. Those not able to understand the language in which a paper was being presented could hear the paper in their native tongue merely be donning the ear-'phones.

REGULATION OF MILK SUPPLIED IN SASKATCHEWAN

Control measures affecting the milk industry are now operative in five of the nine provinces in Canada. Manitoba was the first province to have such regulation, an act being passed in 1932 to bring the milk supply of Winnipeg under the Public Utilities Commission. In Alberta, similar legislation went into effect in August, 1933, controlling milk in Calgary and Edmonton. A separate body to regulate milk in Quebec was set up in April 1933, and in the winter of 1933-34 a milk commission was appointed to supervise the distribution of milk throughout the whole province. A milk control act was passed in the 1933-34 legislative session of Ontario. A separate body, having jurisdiction over the whole province, was appointed to supervise the act. Legislation for milk control in Saskatchewan was also provided at the 1933-34 session of the legislature of that province.

The regulation of milk supplies in Saskatchewan comes under Part III of the Local Government Board Act. The Act was extended to include this legislation as a result of the recommendations made by the Saskatchewan Milk Enquiry Commission, 1933[1]. The Act gives the Local Government Board jurisdiction upon its own initiative or upon complaint in writing, to enquire into any matter relating to the production, supply, distribution or sale of milk. After such enquiry if the board sees fit it may make such regulations or orders as it deems necessary.

The Board may prescribe the area in which regulations shall have effect and may require all persons who distribute, process, or sell milk in any such area to be authorized to do so. The Board may also classify milk producers, processors and distributors and may establish from time to time temporary schedules of prices at which milk shall be supplied by the respective classes. The Board may require distributors to keep adequate records and to report their operations to the Board when asked.

To offset the cost of administration of the regulation of milk supplies the Board may assess producers and distributors in any prescribed area for such sums as may be necessary. If deemed expedient the board may license either producers or processors or distributors and charge a reasonable fee for the licence. Licences may be refused, cancelled or suspended.

The Board also has the powers of inspection and examination. It may enter any building or plant, summon witnesses and require the production of records and accounts.

Every person who violates any regulations of the board is liable to a fine not exceeding $100 per day for each day during which the offence continues.

The board may recommend the appointment of an administrator and such inspectors and other staff as may be necessary to carry out the provisions for the regulation of milk supplies.

The first milk administrative order was issued for Moose Jaw on July 21, 1934. One for Regina followed soon after. Both went into effect on August 1. Order number three was made for Prince Albert, while on October 27, Yorkton, and on October 29, Saskatoon, milk supplies came under regulation.

Complaints in writing from the producers, distributors or both were received by the board from each of the five places mentioned above. The board held enquiries and decided that temporary schedules of prices should be established.

The price established for milk delivered by the producer on August 1, was 45 cents per pound butter-fat in both Regina and Moose Jaw. On October 1, this price was raised to 50 cents in the case of Regina and 52 cents in Moose Jaw. From November 1 to December 31 Saskatoon producers will receive 48 cents per pound butter-fat and Yorkton producers will get $1.55½ per hundred pounds for 3 5 milk with 3 cents added or deducted for each one-tenth above or below 3.5 per cent.

[1] The reader is referred to the Economic Annalist, Volume IV, No. 2, page 19, for a brief review of the recommendations made.

Consumers in Regina, Moose Jaw and Saskatoon pay 10 cents a quart for milk from the distributors. In Yorkton they pay 8 cents per quart. Stores can buy bottled milk at one cent less than this figure and take one cent per bottle spread, except in Regina where the price of bottled milk to stores was raised to 10 cents and to consumers through stores to 11 cents per quart. Hotels and like institutions buying milk in bulk pay 32 cents per gallon in Regina, Moose Jaw and Saskatoon and 26 cents per gallon in Yorkton. Prices for chocolate milk, vi-co, and the various grades of cream are also set for the consumers, stores and hotels. Milk to be separated for the fluid cream trade is paid for at a lower rate to the producer.

Licences are required in each city for all persons who distribute and sell milk. The fee for a licence is three dollars in Regina, Moose Jaw and Saskatoon and one dollar in Yorkton. Producers have not been licensed except in so far as they are distributors.

Payment of a fee of 4/10 of a cent for each pound of butter-fat delivered is required of every producer and 4/10 for each pound sold of every distributor in each of the three larger cities. In Yorkton 1½ cent per hundred pounds of milk is assessed to both distributors and producers.

The distributors in each city must pay the producers on the 20th and 5th of each month. Distributors deduct the fee from the producers' returns and pay the amount to the board together with the fee assessed on them.

Dr. G. H. S. Barton discussed the marketing of farm products in an address delivered before the members of Canadian Society of Technical Agriculturists at a dinner held in the Chateau Laurier, Ottawa, on November 13th. In the course of his address, Dr. Barton pointed out the need for educational work in respect to marketing. These problems, he stated, should be studied by the research method of approach. He gave as a solution to our problem of "abundance" the stimulation of home consumption. Consumption, he said, has been taken for granted in the past; it should now be examined. To stimulate home consumption, producers must supply consumers that which will appeal to them, and products must be of the very best quality. Service to the consumer should become the motto.

Reports of creamery butter production for the nine months ending September 30th, 1934, show a total of 189,473,377 pounds manufactured as compared to 177,988,-052 pounds for the same period of 1933, an increase of nearly 11½ million pounds or 6.45%. All provinces report increases except Prince Edward Island and Nova Scotia. Should creamery butter production be maintained at the increased rate of production of the first nine months, total production for 1934 will show a further increase over the five-year average 1929-33 than was recorded for 1933, which was 6.6%.

The Dominion Marketing Board appointed under the Natural Products Marketing Act, 1934, has approved of five schemes which are now in operation. The first one approved was that for tree fruits produced in certain sections of British Columbia. The second was a scheme to regulate the marketing of apples and pears for export. The third applies to the export to the United States of red cedar shingles, produced in British Columbia. The fourth regulates the marketing of dry salt herring and dry salt salmon produced in British Columbia and the fifth is to control the marketing of flue-cured tobacco in the province of Ontario.

A meeting of the Joint Committee on Economics composed of representatives of the Dominion and Ontario Department of Agriculture and the Department of Economics at the Ontario Agricultural College, and Queens, Toronto and Western Universities was held in Toronto, November 3rd. Research work was reviewed and plans for new work outlined.

PRICE POLICIES

Price cutting is the cause of much complaint among growers and shippers of farm products and constitutes a very difficult problem due to the fact that it may arise from a variety of causes.

In the first place price cutting may be regarded as a form of competition. It is particularly apt to occur in seasons when the existence of an over-supply is known and shippers become panic-stricken in anticipating a sharp fall in prices. It may also occur when there are two or more types of growers, one of which has a lower standard of living than the others. This is particularly true where a large proportion of the work can be done by hand and the operators are willing to accept low prices. It is frequently used by dealers as a means of securing new trade contacts and in increasing sales through established outlets. It may also be used as an advertising device. Very often price cutting arises through the necessity of growers having to sell out a crop early in the season in order that they may secure cash to liquidate debts. Sometimes price cutting takes the form of a rebate. It should be recognized, however, that lower quotations may result from more efficient production or marketing and for this reason price policies must be closely studied in order that the real effect may be understood.

An example of the first mentioned type is found in the case of a large supply which dealers seek to move quickly so that they may dispose of their holdings before the real break in prices occurs. Very often such action precipitates the very situation which it was sought to avoid.

An example of the second type may be found where white growers compete with growers of certain other racial types. The vegetable grower who is not of white origin may utilize hand labour almost exclusively, work long hours, and accept a relatively small cash payment rather than assume the risk of carrying the crop for a longer period so as to adjust supplies more nearly to demand. The offer of an attractive price as a means of securing new outlets is well known and needs little explanation. Sometimes it may happen that brokers may wire for quotations. Inevitably one will be lower than the rest and the broker may then wire another dealer to the effect that the product may be bought at a price below this quotation. The second dealer may then assume that his original quotation was too high and will either quote at the lowest figure previously offered or cut under it. In this way the price is lowered.

An example of price cutting as a means of advertising is found in the "leader" policy adopted by certain stores, in which case a product may be sold below cost in order that customers may be attracted to the stores and in addition to purchasing the leader, will be persuaded to buy products displayed at regular prices.

The relation of "distress selling" to price cutting is pretty well established. A shipper or grower who is in need of cash very frequently will under-quote the generally recognized price in order to secure a quick turnover and satisfy his creditors. One example of the rebate system may be found in the case of a direct purchase by a wholesale receiver from a shipper. The wholesaler may request that the price be lower by the amount of the brokerage charge which has been avoided. This places him in a position to under-quote his competitor and results in lower values for the shipper.

The foregoing illustrations all deal with price cutting among firms assumed to possess equal efficiency. There are, however, circumstances under which competitive conditions result in lower prices because of increased efficiency. A new area of very fertile land may be brought into cultivation and growers in that area may be able to undersell established producers in their own markets. A new and cheaper method of processing may be introduced or an established business may be reorganized so that operating expenses are reduced, and as a result the business may be able to undersell competitors and still make an adequate return to stockholders. Consumers and growers, too, are entitled to the benefits of such efficient service.

From this brief outline of price cutting methods it will be apparent that there is ample room for abuses to creep into business policies. A rigid price is apt to be even less satisfactory because a rigid price which is too low fails to call forth the necessary supply and to stimulate efficient performance of marketing services. Contrariwise a rigid price which is too high may for a time enable excessive profits, but eventually stimulates a surplus. Most farmers' business organizations are obliged to adjust supply to demand as well as can be done, and to market annual supplies of the product excluding a reasonable carryover within the annual cycle of production and consumption. Efforts of independent handlers to stabilize prices through gentlemen's agreements are difficult to enforce and may be questioned on legal grounds. Adjustment of supply to demand is not a simple process because free competition does not always exist. Farmers who are widely scattered find it difficult to make such adjustments unless some central marketing agency operates in their interest. The alternative is to set up legal machinery and safeguards under which growers and dealers in farm products may effect a measure of regulation of marketing without injuring the consumer.

ECONOMIC LITERATURE

MacKintosh, W. A. Canadian Frontiers of Settlement. Volume 1, Prairie Settlement, the Geographic Setting. The MacMillan Company of Canada, Limited, 1934.

This book is the first of nine volumes on the Canadian Frontiers of Settlement. The volumes present some of the results of research carried on by the Canadian Pioneer Problems Committee since its organization in 1929. Dr. Isiah Bowman, Director of the American Geographical Society of New York, has guided the project from the outset, and the Social Science Research Council has, by generous grants of funds, made possible the five-year programme of research and the publication of this and the other eight volumes.

This volume outlines the Geographic setting of Prairie Settlement. The first four chapters deal with the land and the climate, agricultural exploration, railways and settlement, and the spread of settlement.

The settler coming to the Canadian grasslands was confronted with many unfamiliar problems. Frost in the north and drought in the south made crops precarious. Adequate transportation was lacking. In the majority of cases the settler's traditional knowledge was not suited to grappling with the problems which confronted him. Early explorers namely, Captain John Palliser, Sir John Richardson, Dr. Richard King, S. J. Dawson and Professor John Macoun, made studies of the frontier and gave opinions as to the desirability of settlement and probable extent of suitable agricultural land. The need of some market or conveyance for grain was stressed by Sir John Richardson.

In 1878 the first railway reached Winnipeg. It connected the Red River Settlement with St. Paul and Chicago. By 1883, the Canadian Pacific Railway stretched north of the Great Lakes to link Winnipeg with Eastern Canada. In 1885 the first transcontinental line was completed from coast to coast. From a series of maps presented in the book it appears that the railways followed the settler rather than preceded him. For the most part railways now have been built up to the ten-mile limit, that is to say the settler in general is within a ten-mile radius of a railway point.

In Chapters 5 to 8 the various sub-regions of the Canadian interior plain are outlined. The author discusses the climate, topography, agriculture and density of settlement in these sub-regions. Physiographically the interior plain of North America forms one region. The region, however, is subdivided into a number of sub-regions differing from one another in topography, climate, vegetation, and soil. The Canadian section may be divided into five sub-regions: (1) the Red River Valley, (2) the Park Belt, (3) the Prairie Plains, or semi-arid belt, (4) the Forest Belt, and (5) the Peace River Valley.

The Red River Valley has been settled longer than any other part of the Canadian Plains. Its climate and soils are well known and understood. Its problems are not pioneer problems but those of maturity. With changes in land utilization changes in rural population may occur. Increases are somewhat dependent upon a larger market being afforded by the urban area of Winnipeg. With the exception of the Red River Valley, the Park Belt is the most densely settled area of the western plains. Practically all townships in it have a rural population density of five to ten persons or greater. Since the size of farm throughout the Park Belt is increasing as in other areas, it is unlikely that the density of rural population here will increase greatly, except in foreign language settlements.

An especial problem in regard to permanency of settlement exists in the dry belt of the prairie plains area. Permanent settlement of the dry belt will probably be advanced in three ways. First as markets expand some increase in the irrigated areas may be expected. Secondly, areas less favoured in topography and soil but better watered will turn more strongly to grazing. Thirdly, grain growing with improved rotations and improved tillage, larger enterprises with sufficient capital to average the good years with the bad, will use the better soils and the better topography.

Settlement in the wooded area has been difficult and slow. The cost of clearing the land has been a powerful deterrent. In part, the slowness with which railways came to serve the sparse settlements of the Forest Belt was an obstacle to further settlement. Over the whole transitional soil belt from Manitoba to Alberta from 33 to 70% of the land is classed as unsuitable for cultivation. On the basis of this evidence one can predict that the density of settlement in these areas will be low, and that the problem of maintaining adequate transportation, governmental, and social services for the settlements will be correspondingly difficult.

The Peace River Valley is the area in which settlement has been most active during the past decade. The southern boundary of the Peace River Valley is about 54° and the land is being tilled north of 58°. Markets are distant, Grand Prairie being 407 miles from Edmonton; 1,178 miles from Vancouver, and 2,555 miles from Montreal, its two ocean ports. Settlement in the Peace River Valley is so recent and so immature that the ultimate distribution of population is not apparent. It may be predicted, however, that unless restricted by transportation difficulties, population will attain higher densities on the parkland soils.

Chapter 9, deals with climatic variability of the western plains. Over the greatest part of the region it is necessary to conserve moisture, and in considerable areas early maturing grain and speed in farm operations are necessary to avoid the penalties of a short growing season. The margin of safety in both cases is comparatively narrow. The wheat farmer in Western Canada is engaged in a business subject to unusually sharp fluctuations, imposed on it in greater or less degree by pronounced variations in rainfall and the other climatic conditions of wheat growing, and by the necessity of competing in a far distant world market for the sale of a raw material.

Chapter 10, the final chapter, is devoted to a discourse on the probable limits of settlement. Under favourable economic conditions land in farms may be expected to increase by 20 million to 30 million acres, depending upon the proportion of woodland included. The extension of the agricultural area, the substitution of "mixed farming" for grain farming, and the high rate of natural increase among the non-Anglo-Saxon population are factors favourable to an increase in rural population. The extension of mechanization and the increasing size of farms are factors limiting such an increase. Markets for the products of mixed farming are not likely to be extended rapidly; the area of suitable land open for settlement is not large; and the size of farms on the Canadian plains is still considerably less than that in corresponding parts of the plains in the United States. For these reasons, it is likely that further increases in the rural population of the Prairie Provinces will be small, and that in the near future decline may succeed increase.

NOTES

The American Farm Economics Association will hold its twenty-fifth Annual meeting at Chicago, December 26th to 29th inclusive. The American Economic Association and other national associations will meet at the same time. Dr. J. F. Booth, Economics Branch, will present a paper on Measures of Relief and Rehabilitation in Canada and Dr. W. C. Hopper will discuss marketing agreements. Dr. Wm. Allen, University of Saskatchewan, will discuss problems relating to debt adjustment.

The Canadian Society of Agricultural Economics held a local meeting in the C. S. T. A. Rooms, Ottawa, on the evening of November 28th. Dr. J. E. Lattimer, Macdonald College and Dr. T. W. Grindley, Dominion Bureau of Statistics, who recently attended the third International Conference of Agricultural Economists discussed agricultural conditions and policies in Europe. Dr. W. V. Longley, president of the Society, presided.

The organization of the Economics Branch of the Department of Agriculture' Ottawa, has recently been altered to provide for separate Divisions of Farm Management and Marketing. The activities of the Branch will continue to include other work in agricultural economics.

Mr. J. Coke, who since 1930 has acted as Assistant Commissioner of the Agricultural Economics Branch, will also assume the position of Chief, Division of Farm Management. Mr. Coke came to the Economics Branch from the Ontario Agricultural College where he had for some years been a member of the staff of the Economics Department.

Records from about 90 creamery operators were obtained in a recent survey of butter plants in the Prairie Provinces. Tabulation and analysis work on these records will be carried on this winter. In the conduct of this study the Provincial Departments of Agriculture, and the Economics Departments of the Universities of Manitoba and Alberta co-operated with the Dominion Department of Agriculture, Dairy and Economics Branches.

Dr. W. C. Hopper, who was for some years on the staff of the Dominion Experimental Farms but who left to take graduate work in Economics at Cornell University and later to accept a position at Washington, was recently appointed Chief of the Division of Marketing, Economics Branch, Ottawa. Dr. Hopper will also act as Secretary of the Dominion Marketing Board.

Mr. W. F. Chown recently joined the staff of the Economics Branch as Accountant Examiner. Mr. Chown is a graduate of Queens University. He was also for a time student at the Ontario Agricultural College and more recently obtained the degree of Chartered Accountant and admission to the Institute of Chartered Accountants. His work with the Department will be in the field of business and cost analysis.

Through a co-operative arrangement with the Dominion Marketing Board the staff of the Economics Branch will be used by the Board for research and general service when required. Assistance has already been given in connection with two schemes.

The provisional estimate of Canada's 1934 wheat crop is placed at 275,252,000 bushels by the Dominion Bureau of Statistics. Production for 1933 was 269,729,000 bushels. In the Prairie Provinces the provisional estimate of the 1934 wheat crop is 263,000,000 in comparison to a production of 250,841,000 in 1933.